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BOTANICAL GAZETTE

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ON THE ENDOSPERM AND EMBRYO OF PEPEROMIA PELLUCIDA.

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(WITH PLATE 1)

IN the spring of 1899 I began the study of the Piperaceæ, with well-preserved material of the genera Peperomia, Heckeria, and Piper, collected by the late Professor J. E. Humphrey on the unfortunate expedition to Jamaica in 1897. It was soon discovered that seeds were needed for sprouting in order to complete the work, and it was therefore laid aside temporarily and my time given to work on the related genus Saururus.

The recent paper by Professor Campbell ('99) on *Peperomia pellucida* announced results differing from those I had obtained, and led me to reexamine my slides, with the result that I was satisfied with the essential correctness of my former observations, and noted several interesting features in addition. As the intended detailed study of the group may be deferred for some time, an outline of the most important observations thus far made on *Peperomia pellucida* Kunth is given here.

The flower consists of two stamens, and a carpel sessile in the axil of a top-shaped bract (*br*, *fig. 1*). The ovule is single, basal, and orthotropous (*fig. 1*), with a single integument and one archesporial cell. The development of the flower as far as followed agrees with the account given by Schmitz ('72), and the development of the macrospore in the nucellus is as described by Campbell.

The primary archesporial cell cuts off a tapetal cell above, and then immediately forms the definitive macrospore below. The tapetum divides to three or four tiers of cells, which finally form, together with the outer layer of cells of the nucellus, a persistent plug of yellowish thick-walled cells, directly under the micropyle (*tp*, *figs. 1, 2, 9, 13*).

The first four nuclei formed from the large macrospore nucleus are located at the periphery of the pretty dense protoplast of the embryo-sac, arranged like the spores of a tetrad and connected by strands of granular cytoplasm (*es*, *fig. 2*). Soon after this we find eight ellipsoidal peripheral nuclei, imbedded in the cytoplasm surrounding the enlarged vacuole of the embryo-sac. Up to this stage the sequence of phenomena has not been very different from that in the normal angiosperm embryo-sac, except for the lack of the bipolar grouping usually found. But now each of the eight nuclei divides again, as Campbell has shown, to form an embryo-sac with sixteen similar nuclei, pretty uniformly distributed in the peripheral layer of cytoplasm (*fig. 1*). A little later than this, before the pollen tube reaches the embryo-sac, the cytoplasm begins to get denser about one of the nuclei at the top of the embryo-sac, and finally a definite limiting membrane surrounds this and forms the oosphere (*o*, *fig. 1*). This egg is not directly under the micropyle, but is pushed aside slightly by the aggregation of a smaller amount of cytoplasm about a second nucleus at the top of the embryo-sac to form the single *synergid*, as we may call it from its position (*sy*, *fig. 1*). The position of spindles in certain cases seems to indicate that this is a sister cell to the oosphere. Sometimes other nuclei are found near the egg, but often not, and in no case was there seen a definite massing of cytoplasm about any of these. At first the synergid does not have a definite wall, but later on, as it persists, at and after fertilization, a distinct wall can be seen (*sy*, *figs. 3, 7, 9, 11, 12*).

At about the time the pollen tube enters the egg certain of the remaining fourteen peripheral nuclei begin to move together to form a compact group, of usually eight nuclei, surrounded by

cytoplasm. This group may appear at the lower end of the embryo-sac, in the middle near the wall, or center, or above, and near or even in contact with the egg (*espn*, *fig. 3*).

The remaining peripheral nuclei retain their position near the wall, at first as naked nuclei in the thin layer of cytoplasm, but later each of these and a small portion of cytoplasm is separated from the great mass of cytoplasm in the embryo-sac by a flat saucer-shaped wall (*pn*, *figs. 3, 7, 9, 11, 13*). Nowhere was there noticed any tendency of a number of these to collect in a basal position, or anything in their behavior to suggest their homology with the antipodals of the typical angiosperm embryo-sac.

The short top-shaped stamens bear two pollen sacs each. Certain pollen grains (three or four in a section showing fifteen fertile ones) remain with unthickened walls, but apparently are not used for the nourishment of the fertile ones. The nucleus of the finely reticulate-walled pollen grain divides to two at a time soon after the formation of the tapetum in the embryo-sac of the same flower. The pollen grains are shed after the embryo-sac has reached the four-nucleate stage. They lodge on the large abaxial lobe of the carpel (*st*, *fig. 1*), and grow downward through a conical mass of small-celled conducting or nutritive tissue to the fusion canal of the carpel, and thence to the micropyle (*pt*, *fig. 1*). Just when the division of the generative nucleus occurs was not made out with certainty, but in cases where the pollen tube had just reached the embryo-sac the pollen-tube nucleus was seen at its very tip, and a single large generative nucleus, with cytoplasm about it, at the level of the nucellus. In other cases of about the same age there were apparently two generative nuclei.

No indication of a sterile prothallial cell was discovered. The pollen tube often extends some distance into the egg, and after its entrance two nearly similar nuclei are found within the egg. The exact fate of the pollen-tube nucleus and the second generative nucleus was not determined.

For a considerable time after its entrance the male nucleus lies in the egg near or even in contact with the female, but without

fusing with it (*figs. 3, 11*). Its presence in the egg seems, however, to have an important influence on the other contents of the embryo-sac. At the time of its entrance the group of eight nuclei, each with a single nucleolus, is usually found in the central or upper part of the embryo-sac near the egg, surrounded by a considerable mass of cytoplasm, but not separated from each other by cell walls (*espn, fig. 3*). Soon after this the walls of certain of these nuclei are seen to be flattened against each other (*espn, figs. 3, 6*), and a little later still the group may consist of one or two larger, elongated, constricted nuclei, each with two nucleoli, and six or four normal-sized nuclei each with a single nucleolus. These larger nuclei have been formed in each case by the fusion of two of the original nuclei of the group. The first one or two of these fusion nuclei form centers to which the other nuclei of the group draw up closely and fuse on to add their bulk to that of the larger nuclei. Finally a very large nucleus is formed, with at first several normal sized nucleoli, and later fewer very much larger ones or a single one (*espn, figs. 6, 7*). The wall of this large nucleus shows at first several projecting lumps or knobs, each indicating the portion contributed by one of the fusion nuclei (*espn, figs. 4, 5, 6, 7, 8* — a series of sections of the same group). The line of contact of the walls of the fusing nuclei is at first evident by the darkly stained region where the two peripheral chromatin nets press against each other (*espn, figs. 5, 6, 7*). Later the lumps on the wall gradually smooth out and the chromatin net becomes evenly distributed about the periphery of the usually transversely elongated nucleus, which lies in a pretty dense mass of cytoplasm just below the oospore (*espn, figs. 7, 8*).

From this time on this nucleus behaves like the endosperm nucleus of the typical angiosperm embryo-sac. It sometimes begins its development before any activity is noticed in the fertilized egg, except that the wall of the latter becomes more distinct and the sexual nuclei flatten against each other (*fig. 11*). In other cases the sexual nuclei fuse during the fusion of the endosperm-forming nuclei (*fig. 7*). The endosperm nucleus

divides by mitosis, the first spindle being approximately transverse. The number of chromosomes here is seemingly very large, compared with that in other spindles found in the embryo-sac or in the nucellus, but they were so densely packed in all the cases seen that it was impossible to make accurate counts.

It is certain, however, that the amount of chromatin in this and its daughter spindles is greater than that found anywhere else in the plant (*espn*, *figs. 9, 11*). A cell plate is formed in the typical way at the middle of each spindle, the fibers of the latter being stretched out laterally to a surprising extent (*espn*, *fig. 10*). The new cell-wall thus formed stretches from the oospore to the base of the embryo-sac and cuts the latter completely in two, forming thus two endosperm cells. Each of these divides further, forming a cell-wall immediately at each division, till in the oldest seeds seen there are forty or more endosperm cells, each with a large nucleus, several nucleoli, and dense cytoplasm, filling up all of the embryo-sac not occupied by the embryo and synergid and flattening the degenerating peripheral nuclei against the wall of the embryo-sac (*esp*, *figs. 12, 13, 14*, *pn*, *figs. 9, 13*).

The fusion of the sexual nuclei is completed, at the latest, soon after that of the nuclei of the endosperm group, and before many endosperm cells are formed the oospore divides to form the embryo. In the few cases of the early divisions of the embryo seen the first wall seemed to be longitudinal, and the position of the walls in the slightly older embryos, often seen, seemed to confirm this (*em*, *figs. 12, 13*).

The oldest fruits available, as was evident from their position on the spike were nearly ready to separate from the mother plant, *i. e.*, were nearly ripe. In these the embryo consisted of more than twenty cells, but showed no sign of a definite suspensor and no indication of the organs of the young sporophyte. In fact, the whole structure has much the same shape and but slightly larger size than the one-celled oospore (*osp*, *fig. 9*, *em*, *figs. 12, 13*).

The ultimate fate of the long persistent synergid has not been made out with certainty as yet, but so far as it has been definitely traced it retains much the same size and appearance that it has at the time of fertilization, except that the wall becomes more distinct (*sy*, *figs. 3*, *7*, *9*, *11*, *12*). In many cases where the embryo consisted of six or eight cells a single large cell could still be seen beside it, which seemed quite distinct from the endosperm cells that press against the embryo on all other sides, and this is interpreted as the still persistent synergid (*sy*, *fig. 12*), and possibly the cell at the right of the embryo under the tapetal plug in *fig. 13* is another case of the same sort. In several of the very oldest embryos seen there was a group of cells, smaller than any other cells in the embryo-sac, located in in this same position beside the embryo. The evidence obtained points to these as derivatives of the synergid, but further careful work, including probably the study of the sprouting seed, will be necessary to make this certain and to determine the ultimate fate of these cells.

The absolute size of the embryo-sac in these mature seeds is but little larger than when the egg is differentiated (*figs. 2*, *3*, *13*—note the magnification of each). The relative size and position with reference to the other parts of the fruit is shown in *fig. 14*. The oblate spheroidal mass of endosperm is about one eighth the length of the whole seed. It is separated from the integument at the top by three or four layers of cells of the tapetum and nucellus. Below is the great mass of perisperm cells developed from the basal portion of the nucellus (*figs. 12*, *14*). Each of these cells is finally packed closely with starch, aggregated in several masses (filling up the vacuoles) separated by thin layers of cytoplasm (*psp*, *figs. 13*, *14*, *15*), in one of which lies the flattened and distorted, but still darkly staining nucleus (*pspn*, *fig. 15*). In these cytoplasm layers are also found large clear, or finely granular, spherical masses of an undetermined chemical nature, but presumably serving as food (*psp. fig. 15.*)

The single integument is but two cells in thickness, and both of these take part in the formation of the seed coat or

testa. All the walls of the cells of the outer layer become thickened till the cell cavity is practically obliterated, and the thickness of this layer is about the same over the whole of the seed, or slightly greater toward the base (*int*, *figs. 14*, *15*). The cells of the inner layer thicken the outer walls greatly, especially near the upper end of the seed, where large knobs of the thickening substance project into the cell cavity (*int*, *figs. 14*, *15*). The cavity is never entirely filled as in the outer cells, but considerable space remains which is packed with starch like the cells of the perisperm (*int*, *figs. 14*, *15*). The innermost layer of thickening substance of the outer walls of the cells of this layer is of quite different consistency from the rest of the wall, and shows in sections as a uniform border about all the hollows and projections of the latter.

At the base of the seed several layers of cells of the chalaza thicken their walls, like those of the outer integument layer, to complete the protection of the seed (*fig. 14*).

The seed does not escape from the carpel, but the latter apparently remains adhering closely to it when the whole falls from the mother plant. At this time the carpel is four or five layers thick, except at the base and in the stigmatic region (*cp*, *fig. 15*). The outer layer is of large, cuboidal, nearly empty cells, interspersed with knob-like hydathodes. Its cells have unthickened walls, except for the fine striae found quite generally on the outer epidermal walls of the whole inflorescence (*cp*, *fig. 15*). Next within this layer we find two or three layers of thin-walled flattened cells, with little contents. Closely adherent to the integument is the inner layer of the carpel, made up of large cells of about equal height and meridional length, but elongated equatorially to twice this length. These cells have the basal wall considerably thickened, with comparatively low ridges projecting above this general thickening (*fig. 15*). The lateral and outer walls of these cells have anastomosing ribs surrounding thin spots or pits, forming cells closely resembling those of the velamen of the roots of many epiphytes in structure, and perhaps in function also. The basal or inner end of these cells is

occupied by a granular mass, apparently of some firm substance deposited by the protoplast as an addition to the protective layers of the fruit and seed, or possibly connected with the absorption of water by these cells (*fig. 15*).

The subtending bract increases but little in size after the macrospore is formed, and as the fruit ripens the bract withers and is squashed down by the swelling carpel (*br. figs. 1, 14*).

In comparing the foregoing with Campbell's results it will be seen that my observations confirm his in regard to the origin of the macrospore and its development to a sixteen-nucleate ripe embryo-sac. Campbell thinks that one of the upper of these nuclei goes to the egg, and one to each of the two naked synergids; while eight others, which he interprets as probably antipodals, temporarily collect at the base of the embryo-sac, but later disperse and become indistinguishable. The other five nuclei play no prominent part, there being according to his observations no nuclear fusion analogous to that of the polar nuclei of the ordinary angiosperm embryo-sac.

In my own work I have seen but a single synergid which is long persistent and has a distinct wall. The nuclei of the group which Campbell interprets as possible antipodals I find are ultimately fused together into one endosperm nucleus, there being no special basal (antipodal) group of sterile cells or nuclei.

Again, Campbell says that the at first flattened embryo finally fills the whole embryo-sac and that there is no endosperm whatever, while I find that the embryo is nearly globular at first and is later completely surrounded by endosperm which fills the greater bulk of the embryo-sac.

The meaning of these very striking peculiarities of the embryo-sac of *Peperomia pellucida* (and other species of the same genus) is not easy to determine. The extra division of the embryo-sac is quite unique, and so also is the lack of a basal group of sterile cells or antipodals. Finally the fusion of so large a number of nuclei into one, in forming the endosperm nucleus, is approached only by the cases of fusion, at quite a

different stage of development, of the several nuclei in the endosperm cells of *Staphylea pinnata* and *Corydalis cava.* In these forms, according to Strasburger (**'80**), when walls appear about the endosperm nuclei several of these are enclosed in a single cell and these later fuse to a single nucleus. The fusion of polar nuclei during instead of before fertilization is found also in *Allium fistulosum* (Strasburger **'79**, p. 21), and this case may perhaps be considered as analogous to that of the endosperm-forming nuclei in Peperomia.

That these peculiarities of Peperomia are to be considered primitive rather than higher specializations seems to me unwarranted by the evidence at present available, especially when we consider the fact, which I have ascertained, that such closely related genera as Piper, Heckeria, and Saururus have essentially typical angiosperm embryo-sacs. These latter forms develop a small amount of endosperm in a manner similar to that found in such distantly related and certainly not very primitive forms as the Nymphaeaceæ.

Again, the lack of any grouping of the extra peripheral nuclei in the embryo-sac of Peperomia fails to give any encouragement from this source to those who look upon the antipodal group in the angiosperms as a second egg-apparatus (Lotsy, **'99,** p. 106).

So also the fusion of the eight nuclei to form the endosperm nucleus, if we regard it as at all homologous with that of the polar nuclei, seems to indicate that this is a purely vegetative or nutritive process, rather than anything like a sexual fusion as suggested by Mann (**'92**). Finally, the development of the cell walls in the endosperm directly after nuclear division each time, instead of by the method of free cell formation, as in the prothallus of the higher pteridophytes, is not favorable to the view that Peperomia is a transitional form between these forms and the typical angiosperms.

I am inclined to believe that the peculiarities of the embryo-sac of Peperomia have been secondarily acquired, and are analogous to those found in other angiosperms of peculiar habit, *e. g.*, many aquatic, parasitic, and saprophytic forms.

It is probable that a careful study of the sprouting seed will show the meaning of some of these peculiarities to the plant. I hope soon to be able to determine whether the tissue which I have called endosperm here has the same function as in Saururus, of absorbing the perisperm for the benefit of the embryo during the sprouting of the seed. I trust also that a further study of related forms may discover some intermediate type of embryo-sac, that will indicate more definitely the possible derivation of the peculiar one found in Peperomia.

In conclusion and summary: the macrospore nucleus of *Peperomia pellucida* forms sixteen free nuclei, of which one goes to the egg, one to the synergid, eight more fuse to form a single endosperm nucleus, while the other five remain sterile and degenerate. The nearly ripe seed contains an embryo of fifteen or more cells surrounded by endosperm cells in which the walls are formed directly from the cell plate of the spindle.

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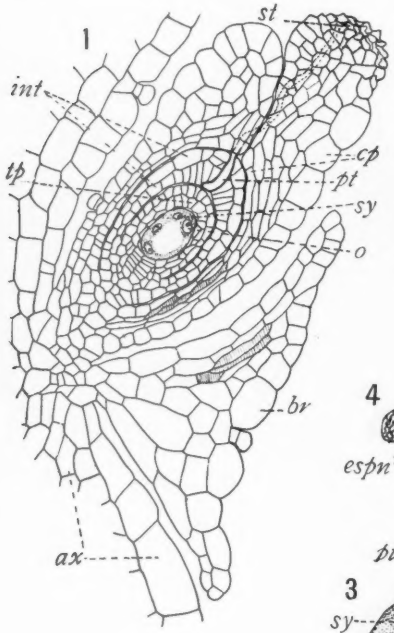
EXPLANATION OF PLATE I.

Abbreviations used: *ax*, axis of the inflorescence; *br*, subtending bract; *cp*, carpel; *em*, embryo; *es*, embryo-sac; *esp*, endosperm; *espn*, endosperm nucleus; *esv*, principal vacuole of embryo-sac; *esw*, wall of embryo-sac; *int*, integument; *mp*, micropyle; *nc*, nucellus; *o*, oosphere nucleus; *osp*, oospore;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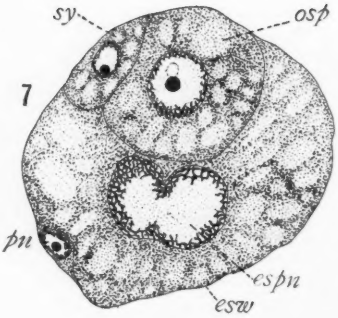
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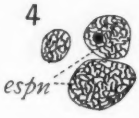
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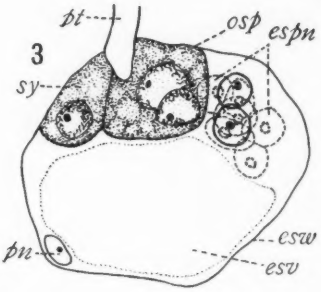
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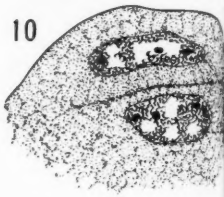
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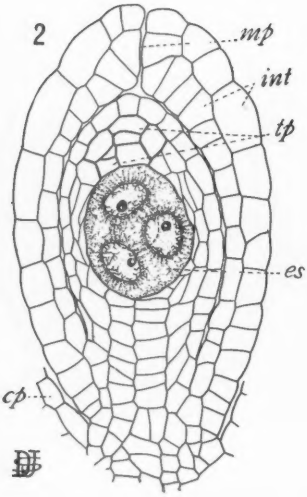
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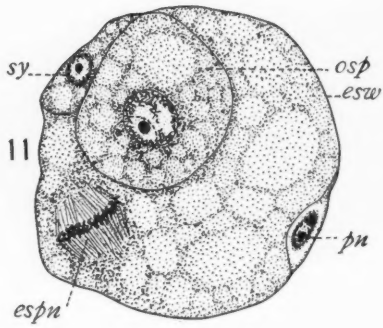
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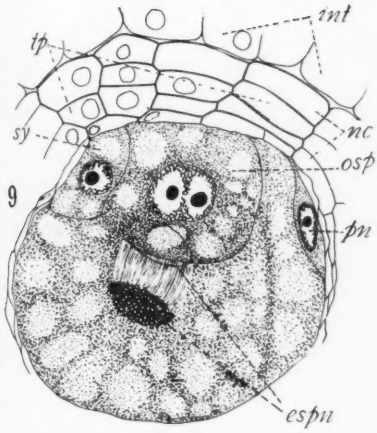
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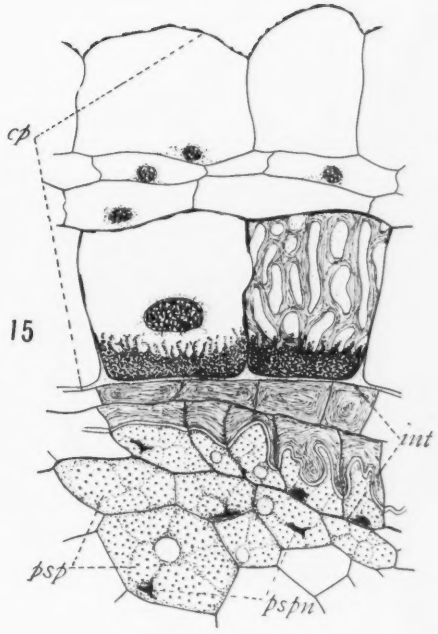
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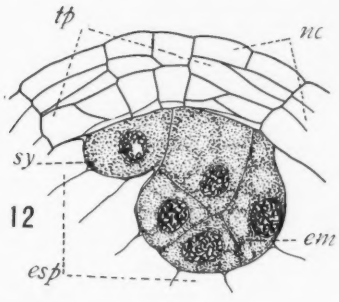
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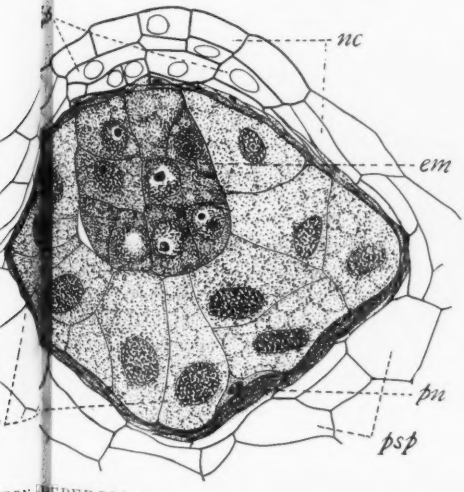
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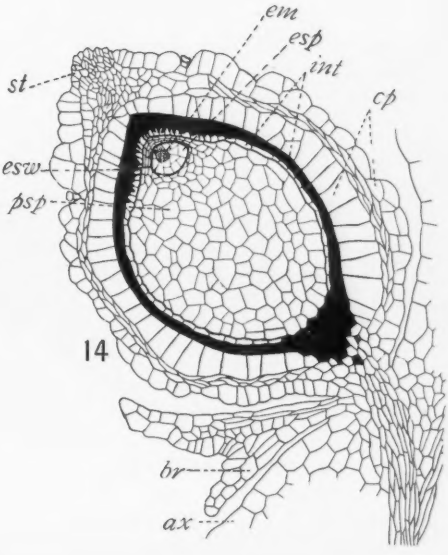
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pn, peripheral nucleus of the embryo-sac; *psp*, perisperm: *pspn*, nucleus of perisperm cell; *pt*, pollen tube; *st*, stigmatic lobe of carpel; *sy*, synergid; *tp*, tapetal cells.

All figures are camera drawings from microtome sections.

FIG. 1. Longitudinal section of axis, bract, and carpel containing nearly ripe (sixteen-nucleate) embryo-sac. × 150.

FIG. 2. Longitudinal section of an ovule with a four-nucleate embryo-sac. × 440.

FIG. 3. Longitudinal section of an embryo-sac after the entrance of the pollen tube and male nucleus into the egg, and showing the group of nuclei that fuse to form the single endosperm nucleus (those with dotted outlines are in the next section to the one from which the rest of the figure is drawn). × 775.

FIGS. 4–8. A series of sections of a group of nuclei fusing to form the endosperm nucleus, in an advanced stage of fusion and with large fused nucleoli; in *fig. 7* the other contents of the embryo-sac are shown; the figures are numbered in the order of succession of the sections. × 775.

FIG. 9. Longitudinal section of embryo-sac, showing the fusion of male and female nuclei in the egg, and a spindle of the second division of the endosperm nucleus; the upper nucleus of spindle from another section. × 775.

FIG. 10. Part of a tangential section of embryo-sac, showing beginning of the formation of a cell-wall from the cell plate of the dividing endosperm nucleus. × 775.

FIG. 11. Approximately transverse section of the upper end of an embryo-sac like that shown in *fig. 9*. × 775.

FIG. 12. Longitudinal section of the upper end of an embryo-sac through the synergid and an eight-celled embryo. × 775.

FIG. 13. Longitudinal section through the upper end of nucellus of a nearly ripe seed, containing an embryo of twenty or more cells surrounded by endosperm. × 775.

FIG. 14. Longitudinal section through axis, bract, and a nearly ripe fruit; endosperm and embryo practically as in *fig. 13*. × 75.

FIG. 15. Part of section of carpel, integument, and perisperm from *fig. 14* (at the left from the base of the embryo-sac). × 775.

NEW OR UNRECORDED MOSSES OF NORTH AMERICA. I.

J. CARDOT and I. THÉRIOT.[1]

(WITH PLATES II–V)

PHASCUM CUSPIDATUM Schreb. var. **Americanum** Ren. & Card., var. nova.— Costa longe excurrente apice saepius decolorata varietati *piliferum* proximum, sed foliis brevioribus, superne magis papillosis pedicelloque brevissimo erecto distinctum. Varietas *mitraeforme* Limpr., foliis papillosis similis, differt foliis majoribus longioribusque, costa minus longe excurrente et calyptra conico-mitraeformi.

Wisconsin: Madison, on ground in pastures, clover fields, and fallow ground (L. S. Cheney, 1893. Ren. & Card., *Musci Amer. sept. exsicc.*, no. 267). Missouri: old fields near Emma (C. H. Demetrio, 1891). Illinois: —

Microbryum Floerkeanum var. *Henrici* Ren. & Card. in BOT. GAZ. **14**: 91. 1899, from Kansas, leg. Henry, seems to be also a stunted form of the same moss. It has also the calyptra cucullate, a character which separates it from *Microbryum Floerkeanum*.

All the specimens we have received from North America as *Phascum cuspidatum* belong to this var. *Americanum*.

GYMNOSTOMUM CURVIROSTRE Hedw. var. COMMUTATUM Card. & Thér. (*Hymenostylum commutatum* Mitt., Musci Ind. Or., p. 32. *Weisia curvirostris* var. *commutata* Dicks., Handb. Brit. Mosses, 212).

Newfoundland (Rev. A. C. Waghorne).

This variety has long, narrow leaves, and the cells of the areolation are everywhere long and smooth. In the type, the upper areolation is composed of irregular cells, rectangular, quadrate, and triangular, with scattered papillae.

GYMNOSTOMUM CURVIROSTRE Hedw. var. SCABRUM Lindb., Musci Scand. 22.

[1] Besides the new species, we shall describe in this paper and the following several species named by Renauld and Cardot in the *Revue Bryologique*, 1892–1893, but of which only short, provisional diagnoses were published.

Missouri: Benton county, on moist rocks along Indian creek (C. H. Demetrio, 1893). Minnesota: Lewiston cave (J. M. Holzinger, 1889), Bear creek (J. M. Holzinger, 1890). Wisconsin: Madison (L. S. Cheney, 1892. Ren. & Card. *Musci Am. sept. exsicc.* no. 269).

This form shows contrary variations to the preceding: the leaves are smaller, the cells quadrate, papillose; besides, the stem and the nerve are generally covered with high papillae.

HYMENOSTOMUM MICROSTOMUM R. Brown, Trans. Linn. Soc. **12**: 572 (*Gymnostomum microstomum* Hedw., Musc. frond. **3**: 71, *pl. 30 B*).

According to Lesquereux and James, *Manual* 56, this species is not known from North America, and all the specimens that have been communicated under the generic name *Hymenostomum* are to be referred to the *Weisia viridula* var. *gymnostomoides* C. Müll. Yet the no. 54 of Sullivant and Lesquereux *Musci Bor. Am.* belongs undoubtedly to the *Hymenostomum microstomum* R. Br., at least in our set.

Quite inseparable from *Weisia viridula* as to the vegetative organs, and differing only by the capsule closed with a membrane finally perforated in the center.

Weisia Wimmeriana BS., Bryol. Eu. 33–36: 4, *pl. 1.* (*Gymnostomum Wimmerianum* Sendtn. in Flora **23**[1]: 59. 1840. *Hymenostomum murale* Spr. Musc. Pyr. no. 236. *Gymnostomum murale* Sch. Syn. 37. 1860. [Ed. 1.])

Minnesota: Taylor's Falls (J. M. Holzinger, 1895).

Resembling the slender forms of *W. viridula* in size, habit, shape, and areolation of the leaves; distinct chiefly by the inflorescence, which is paroicous, or sometimes, as in our Minnesota specimens, synoicous. The peristome is generally rudimentary; in our American specimens, however, the teeth are rather perfect, with 4–5 articulations.

DICHODONTIUM OLYMPICUM Ren. & Card., Rev. Bryol. **19**: 74. 1892.— Dioicum, humile, caespitosum, obscure viride. Caulis gracilis, erectus, 5–7^{mm} altus. Folia madida patentia subrecurva, sicca laxe erecto-flexuosa, apice incurvata, 1.50–1.75^{mm} longa, 0.6^{mm} lata, e basi ovata vel oblonga paulo latiore breviter lingulata, obtusa subobtusave, subundulata, marginibus plana, cellulis prominulis minute crenulata, supra basin integram distincte denticulata, costa valida percurrente vel subpercurrente; cellulae

minutae, obscurae, parietibus incrassatis, irregulariter quadratae, 5–8μ metientes, utraque pagina papillis prominentibus ornatae, cellulae inferiores majores, elongate rectangulares, laeves. Folia perichaetialia longiora, basi laxius reticulata, superne papillis elongatis subcylindricis obsita. Capsula in pedicello pallido, 6–7^{mm} longo, siccitate dextrorsum torto erecta inclinatave, oblonga, arcuatula, circa 1.5^{mm} longa, 0.5^{mm} crassa, collo distincte strumoso, sicca plicatula et sub ore leniter constricta; operculum ignotum. Peristomium purpureum, elatum, dentibus triangulari-lanceolatis, 15–20-articulatis, usque ad medium in 2–3 crura subulata fissis, longitudinaliter striolatis minuteque granulosis. Planta mascula ignota. *Plate II.*

Washington: Olympic mountains (L. F. Henderson).

A true miniature of *D. pellucidum* Sch., from which it is easily distinguished by the much smaller size, the leaves denticulate above the base, the cells of the areolation much smaller and with more prominent papillae and the strumose neck of the capsule.

DICRANELLA LAXIRETIS Ren. & Card., Rev. Bryol. **20**: 30. 1893.— Dioica, pusilla, gregaria. Caulis simplex, brevissimus, 1–2^{mm} altus. Folia madida mollia, erecto-patentia, sicca flexuosa subcrispata, ascendendo sensim majora, circa 2^{mm} longa, 0.25–0.3^{mm} lata, lineari-lanceolata, apice obtuso minute denticulato, marginibus integris planis vel parce reflexis, costa percurrente vel sub summo apice evanida, rete laxo, cellulis inferioribus majoribus elongate rectangulis, superioribus breviter rectangulis subquadratisve, omnibus parietibus angustis. Folia perichaetialia vix diversa. Capsula in pedicello tenui pallido, 5–6^{mm} longo, erecta, minuta, oblongo-subcylindrica, arcuatula, 0.75–1^{mm} longa, operculo convexo oblique longe subulato. Annulus e duplici vel triplici serie cellularum compositus. Peristomii dentes purpurei, valde trabeculati, longitudinaliter striolati, usque ad $\frac{2}{3}$ inferiora in 2 crura longa subulata bifidi. Planta mascula ignota. *Plate III.*

Louisiana: in a deep and shaded ravine near Lafayette (A. B. Langlois, 1891).

One of the smallest species, resembling *D. debilis* L. & J., but with shorter stems, softer and more flexuous leaves, which are minutely denticulate

at apex, softer areolation of wider, shorter, and thin-walled cells, and narrower rather asymmetrical capsule.

DICRANELLA HOWEI Ren. & Card., Rev. Bryol. **20**: 30. 1893, et in Bull. de l'Herb. Boissier **4**: 15. 1896.— Dioica, caespitosa, subnitens, lutescenti-viridis. Caulis erectus, simplex vel parcissime divisus, 6–10^{mm} altus. Folia laxiuscula sicca erecto-flexuosa, madida plerumque plus minus subsecunda, 1.5–2.2^{mm} longa, 0.28–0.35^{mm} basi lata, lanceolato-subulata, acuta subacutave, integerrima vel summo apice obsoletissime denticulata, marginibus ubique planis, costa lata, ¼–⅓ basis et totam fere subulam occupante, cellulis angustis, linearibus, inferioribus brevioribus. Folia perichaetialia e basi subvaginante longius et tenuius subulata. Capsula in pedicello rubello, siccitate sinistrorsum torto, 5–7^{mm} longo, subhorizontalis, oblonga, arcuata, circa 1^{mm} longa et 0.28–0.35^{mm} crassa, sicca sub ore valde constricta, operculo alte conico. Annulus nullus. Peristomium *D. variae.—Plate III.*

California: Mt. Tamalpais, Marin county, on wet banks (Marshall A. Howe, 1892–1893. Ren. & Card., *Musci Amer. sept. exsicc.* no 203).

Very closely allied to *D. varia* Sch., of which it may be only a subspecies or a regional race; characterized by the more distant and more flexuous leaves, subsecund when moist, generally longer, plane on the borders, the broader nerve, the narrower cells, the somewhat narrower capsule in dry state, and the green-yellowish and brighter tinge of the tufts.

DICRANUM VIRIDE BS. var. **laeve** Ren. & Card., var. nova.— A forma typica habitu multo laxiore foliisque minus congestis dorso laevibus distincta.

Newfoundland: Bay-of-islands, old stump (Rev. A. C. Waghorne, 1895).

DICRANUM ANGUSTUM Lindb., Soc. pro Fauna et Fl. fenn. 1880, et Rev. Bryol. **9**: 83. 1882. Lindb. & Arn., Musc. As. Bor. **2**: 80 (descriptio locupletissima).

Northwest shore of Hudson Bay, lat. N. 63°55′, long. O. 90°20′ (G. Comes, 1893–1894). We found some stems of this rare species amongst specimens of *Aulacomnium turgidum*.

A polar moss, known only from some localities of north Finland and from Siberia. It is easily distinguished from *D. Bonjeani* De Not. (*D.*

palustre BS.) by the leaves straight, not undulate, convolute, and entire, the thinner costa, the less porose cells, and the perichaetial leaves long piliferous.

FISSIDENS BRYOIDES Hedw., var GYMNANDRUS Ruthe, Hedwigia 9:178. 1870. Limpr. Laubm. 1:430. (*F. gymnandrus* Buse Musc. neerl. exsicc. fasc. 4, no. 77).

Northwestern Montana: in the vicinity of Lake MacDonald, Flathead county (J. M. Holzinger and J. B. Blake, 1898).

A peculiar form, easily distinguished from the type by the antheridia naked in the axils of the stem-leaves.

FISSIDENS SUBBASILARIS Hedw. var. **Bushii** Card. & Thér., var. nova.— A forma typica differt foliis latioribus brevioribusque, obtuso rotundatis, nervo fere ad apicem producto et areolatione magis opaca cellulis parietibus crassioribus.

Missouri: Eagle rock, on gravelly ground (B. F. Bush, 1897).

Desmatodon systilioides Ren. & Card., sp. nova.— Monoicus, gregarius. Caulis brevis, erectus, 2–3^{mm} altus. Folia in rosulam congesta, patula, oblongo-lanceolata, apice sat subito breviterque acuminata, acuta, marginibus planis superne inaequaliter denticulatis, nervo valido rufescente percurrente vel breviter excedente, cellulis inferioribus laxissimis, subrectangulis, inanibus, hyalinis vel lutescentibus, mediis et superioribus minutis, rotundato-subquadratis vel subhexagonis, papillis numerosis obscuratis, marginalibus 2–4-seriatis, quadratis vel breviter rectangulis, vix vel parum papillosis, limbum distinctum lutescentem translucentem efformantibus. Folia perichaetialia vix diversa, paulo breviora. Capsula in pedicello lutescente vel pallide rubente, siccitate dextrorsum torto, 8–12^{mm} longo erecta, breviter oblonga, brunnea, operculo oblique breviterque conico, subrostrato, apici columellae diu adhaerente, annulo peristomioque, ut videtur, nullis. Sporae laeves, 18–20μ crassae.—*Plate II.*

Labrador: l'Anse-au-Mort (Rev. A. C. Waghorne, 1894).

By the lid attached to the columella and persistent after the opening of the capsule this species resembles *D. systylius* BS., but is clearly distinct from it by the leaves of a more obscure and more papillose areolation, with a distinct pellucid yellowish border, the nerve stouter, brownish, not or very

shortly excurrent, and by the total lack of peristome; at least, all the capsules we have been able to examine do not show the slightest trace of this organ. The pellucid border of the leaves shows some relationship between *D. systylioides* Ren. & Card. and *D. Porteri* James, but the latter has a much narrower capsule with a highly conic lid not adhering to the columella, and the peristome and annulus are well developed.

Barbula eustegia Card. & Thér., sp. nova.— Dioica? gregarie caespitosa. Caulis brevissimus, 1–2^{mm} altus. Folia siccitate erecto-flexuosa, madida recurvo-patula, lineari-lanceolata, acuta, subacuta obtusiusculave, superne plicato-canaliculata, inferiora minima, 0.5^{mm} longa, superne sensim majora, superiora 1^{mm} longa, marginibus planis vel parce revolutis, integris, costa sub apice evanida vel eum fere attingente, dorso papillosa, cellulis inferioribus pellucidis, laxiusculis, laevibus, oblongis, subrectangularibus, sequentibus quadratis, superioribus parvis, vix 4–5μ metientibus, quadrato-rotundatis, obscuris, minute papillosis. Folia perichaetialia caulinis majora, externa e basi semivaginante sat subito in acumen elongatum canaliculatum, patulo-arcuatum constricta, interna oblonga, late breviterque acuminata, rete omnino pellucido. Capsula in pedicello capillari pallido, 12–18^{mm} longo, siccitate dextrorsum torto, erecta vel obliqua, oblonga, 1–1.2^{mm} longa, 0.3–0.4^{mm} crassa, operculo conico-subulato capsulam aequante vel superante. Annulus duplex, 0.07^{mm} latus. Peristomium purpureum, membrana basilari 0.08^{mm} alta, dentibus circa 1^{mm} longis bis convolutis, valde granulosis. Sporae laeves, 8μ crassae. Flores masculi ignoti. Verisimiliter dioica.—*Plate IV.*

Idaho: Cedar creek, Latah county, on ground (L. F. Henderson, 1897).

This moss, received from Mr. Henderson only in very small quantity, seems a miniature of *B. flavipes* BS., from which, besides in its small size, it differs chiefly by the lid as long as the capsule or even longer. By this character, as well as by the form of the leaves, it resembles also *Trichostomum dicranoides* Sch. (*T. macrostegium* Sull. Icon. Suppl. 35, *pl. 22*) from Central and South America and the Antilles, which has been also recorded from Alabama; but this last species has the beak of the lid thinner, the leaves larger, broader, denticulate above, a less opaque areolation of larger and more distinct cells, and the peristome less twisted, with a shorter basilar membrane.

Grimmia pseudo-montana Card. & Thér., sp. nova.— Dioica, obscure viridis, densiuscule pulvinata. Caulis erectus, dichotome ramosus, circa 1^{cm} altus. Folia sicca et madida erecta, subimbricata $1.75–3^{mm}$ longa, 0.75–1 lata, ovato-lanceolata, marginibus planis integerrimis, inferiora mutica, superiora pilo breviusculo minute denticulato, basi paulo decurrente instructa, costa sat valida, basi 60–80μ lata, superne canaliculata, apicem versus indistincta, cellulis inferioribus juxta costam linearibus, lutescentibus, margines versus quadratis vel breviter rectangulis, hyalinis, caeteris parvis, obscuris, quadratis vel subrotundatis, bistratosis. Folia perichaetialia subsimilia, basi laxius reticulata. Calyptra cucullata. Capsula in pedicello crassiusculo stricto, $1.5–2.5^{mm}$ longo, exserta, erecta, breviter oblonga, sicca subcylindrica, exannulata, operculo convexo-rostrato. Peristomii dentes flammei, circiter 0.35^{mm} alti, integri vel parcissime perforati, e basi late triangulari longe subulati, superne minute granulosi, articulis 15–25.—*Plate IV.*

Idaho: near Moscow, on dry rocks (L. F. Henderson, 1894).

Closely allied to *G. montana* BS., but sufficiently distinct by the larger leaves, with a stouter nerve and a shorter and a thicker hair, and chiefly by the peristomial teeth almost entire, not divided and scarcely perforated, with more numerous articulations.

GRIMMIA MONTANA BS. var. **Idahensis** Ren. & Card., var. nova. — A forma typica differt capsula pro more majore magisque exserta et pedicello paulo longiore, siccitate plerumque flexuoso subgeniculato. Folia pilo saepe destituta.

North Idaho: west end of Lake Pend d'Oreille (J. B. Leiberg, 1892. Ren. & Card., *Musci Amer. sept. exsicc.* no. 289).

GRIMMIA SUBSULCATA Limpr., Laubm. 1: 757.

Idaho (J. B. Leiberg, 1889; J. H. Sandberg, 1892). Northwestern Montana: in the vicinity of Lake MacDonald, Flathead county (J. M. Holzinger and J. B. Blake, 1898).

A long time confused with *G. alpestris* Schleich. The distinctive characters quoted by Limpricht are: for *G. alpestris*, pedicel straight, capsule without stomata, leaves not plicate; and for *G. subsulcata*, pedicel somewhat curved, capsule with stomata, leaves with two longitudinal folds in the upper

part. The last character is the best, for the pedicel of *G. subsulcata* is sometimes nearly straight and the capsule without stomata, while the folds of the leaves are always distinct, especially on a transverse section.

It is to be noticed that Limpricht cites erroneously *G. lamellosa* C. Müll. as a synonym for *G. alpestris:* on the contrary, from an original specimen Müller's plant is proved identical with *G. subsulcata.*

The true *G. alpestris* Schleich. has been gathered by Messrs. J. M. Holzinger and J. B. Blake in the same region of northwestern Montana where they have collected *G. subsulcata.*

Orthotrichum Idahense Card. & Thér., sp. nova.— Monoicum, laxe depresso-pulvinatum, inferne fuscum, superne lutescenti-viride. Caulis basi decumbens, longe denudatus, irregulariter ramosus, 2–3^{cm} longus, ramis ascendentibus. Folia madida erecto-patentia, sicca erecto-appressa, 1.75–2.50^{mm} longa, 0.50–0.75 lata, oblongo-lanceolata, subobtusa, integra, marginibus fere e basi usque infra apicem arcte lateque revolutis, costa subpercurrente; cellulae ubique unistratosae, parietibus valde incrassatis, inferiores rectangulares, juxta costam lineares, margines versus quadratae vel breviter oblongae, caeterae rotundae, utraque pagina papillis grossis bi-trifurcatis obsitae. Folia perichaetialia subconformia, basi laxius reticulata. Vaginula nuda. Capsula in pedicello brevissimo vix emersa vel semi-emersa, madida ovata, collo brevi attenuata, sicca subcylindrica, infra os leniter constricta, octostriata, striis e cellulis 4-seriatis, longioribus, lutescentibus, parietibus crassioribus compositis, stomatibus emersis. Operculum ignotum. Peristomii dentes 8 bigeminati, vel 16, siccitate reflexi, plus minus pertusi, minute granulosi, superne lineolati; cilia nulla vel fugacia. Calyptra lutescens, apice fusca, ramentis longis, numerosis, denticulatis, papillosis obsita. Sporae papillosae, 20–22μ crassae. Flores masculi sessiles.— *Plate V.*

Idaho: Moscow mountains, on rocks (L. F. Henderson, 1893).

By the superficial stomata and the peristome reflexed when dry and finely papillose this species belongs to the group of *O. arcticum* Sch., but is easily distinguished from all the other species of this group by its lax tufts, emergent capsule, and peristomial teeth less opaque, covered with less dense papillae.

ORTHOTRICHUM LYELLII H. & T. var. **Howei** Ren. & Card., var. nova.— A forma typica differt capsula exserta in pedicello eam aequante foliisque usque medium versus revolutis. Ab *O. papilloso* foliis minus flexuosis, siccitate strictulis, longius revolutis, acumine breviore et minus angusto distincta. Calyptra valde pilosa. Papillae foliorum parum prominentes. Folia nonnullis propagulis saepe instructa.

California: region of the upper Sacramento, Sisson, on trunks of *Quercus Kelloggii* (Marshall A. Howe, 1894. Ren. & Card. *Musci Amer. sept. exsicc.* no. 291).

WEBERA CARINATA Limpr., Laubm. **2**: 261. (*Bryum carinatum* Boul., Musc. de la France 280. *B. naviculare* Card., Rev. Bryol. **13**: 27. 1886, et *B. cymbuliforme* Card., *loc. cit.* **14**: 22. 1887. *Webera cucullata* var. *carinata* Husn., Muscol. Gall. 229).

Northwestern Montana: in the vicinity of Lake MacDonald, Flathead county (J. M. Holzinger and J. B. Blake, 1898).

By the habit and the dioicous inflorescence, this moss approaches *W. commutata* Sch., from which it differs in the more slender stems, the leaves always plane on the borders, distinctly carinate on the back, imbricated in five rows, and the cell walls thinner.

Bryum euryloma Card. & Thér., sp. nova.— Dioicum, dense caespitosum, lurido-viride. Caulis erectus, tomentosus, 2–3^{cm} altus. Folia conferta, madida erecto-patentia, sicca subappressa, e basi decurrente anguste lanceolata, 3–4^{mm} longa, 0.65–0.75^{mm} lata, sensim et tenuiter acuminata, integra vel apice obsoletissime denticulata, marginibus anguste revoluta, interdum uno latere subplana, nervo in cuspidem breviusculam, acutissimam, apice saepe decoloratam, subintegram vel denticulatam excurrente. Areolatio *B. pseudotriquetri*, limbo autem latiore e 5–6 seriebus cellularum composito. Folia perichaetialia intima minora, triangulari-lanceolata, sensim cuspidata, margine plana. Capsula in pedicello 15–20^{mm} longo basi atropurpureo, abrupte pendula, angusta, subcylindrica, sicca sub ore constricta, collo longe attenuato in pedicello sensim defluente instructa, 2.50–4^{mm} longa, 0.75–1 crassa, operculo convexo apiculato. Peristomium *B. pseudotriquetri*. Flores masculi capituliformes.— *Plate V.*

Puget sound, Orcas island, Mt. Constitution, lake border (L. F. Henderson, 1892).

Distinct from *B. pseudotriquetrum* Schw. and allied species by the smaller size, the narrower leaves entire or scarcely denticulate at apex with broader margin, and the capsule smaller, narrower, and more abruptly pendulous.

BRYUM CRASSIRAMEUM Ren. & Card. var. **Covillei** Ren. & Card., var. nova.— A forma typica differt cespitibus densioribus, caulibus ramisque gracilioribus, strictioribus, foliis strictis magis appressis, costa pro folii magnitudine plerumque crassiore, capsula fusco-rubra et peristomii interni segmentis dorso latius apertis.

Rocky mountains (Death valley Expedition, no. 1358; F. V. Coville and F. Funston, 1891).

BRYUM TORQUESCENS BS., Bryol. Eur. 6–9: 49, *pl. 20*.

Washington: Pullman, Whitman county, moist banks (L. F. Henderson, 1892).

Nearly allied to *B. capillare* L., but distinct by the synoicous inflorescence and the capsule deep red when mature. The American form differs from the European type by the leaves being erecto-patent and not spirally contorted in dry state.

PTEROGONIUM GRACILE Sw. var. **Californicum** Ren. & Card., var. nova.— A forma typica Europaea differt foliis longioribus longiusque acuminatis cellulisque alaribus minoribus.

California: "ad rupes Californiae, perfrequens; Bolander" (Sulliv. et Lesq. *Musci bor. amer. exsicc.*, ed. 2, no. 349); Sansalito (Marshall A. Howe, 1892); Coast Range mts., San Mateo county, on trees (Marshall A. Howe, 1895; Ren. and Card., *Musci Amer. sept. exsicc.* no. 316). All the Californian specimens of *P. gracile* that we have examined belong to this variety.

PYLAISIA POLYANTHA Sch. var. **drepanioides** Ren. & Card., var. nova.— Forma peculiaris, habitu et magnitudine *Hypno pallescenti* similis; folia secunda plerumque ad basin acuminis obsolete denticulata, cellulis alaribus minus numerosis et minus obscuris, rete magis scarioso. Capsula minor. Peristomium normale.

Minnesota: without locality or name of collector, mixed with a small form of *Hypnum uncinatum* Hedw. (Herb. Univ. of Wisconsin).

PSEUDOLESKEA PATENS Limpr. Laubm. **2**: 806. (*Leskea? patens* Lindb. in Soc. pro Fauna et Fl. fenn. 1880. *Lesquereuxia patens* Lindb. in Meddel. af Soc. pro Fauna et Fl. fenn. 14: 75. 1887.

Newfoundland: Deer lake (Rev. A. C. Waghorne).

This species differs from *P. atrovirens* in its more slender stems, the leaves erecto-patent (not secund), symmetric (not falcate), and the papillae being set on the middle of the cells and not on the angles.

TRIPTEROCLADIUM LEUCOCLADULUM (C. Müll.) Jaeg. var. **camptocarpum** Card. & Thér., var nova.— A forma typica differt tantum capsula brevi, subhorizontali, arcuata, brachythecioidea.

Idaho: Latah county (L. F. Henderson, 1894).

AMBLYSTEGIUM SERPENS Br. Eur. var. **subenerve** Ren. & Card., var. nova.— A caeteris formis minoribus *A. serpentis* differt foliis enervibus vel subenervibus. Ab *A. subtili* habitu robustiore, foliis multo majoribus latioribusque, brevius accuminatis distinctum.

Newfoundland: Bay-of-islands (Rev. A. C. Waghorne).

AMBLYSTEGIUM FLUVIATILE Br. Eur. var. **brevifolium** Ren. & Card., var. nova.— A forma typica Europaea caule magis regulariter pinnato foliisque minoribus, brevioribus, ovato-acuminatis, costa pro folii magnitudine crassiore distinctum.

Minnesota: Lanesboro (J. M. Holzinger, 1894. Ren. and Card. *Musci Amer. sept. exsicc.* no. 327).

AMBLYSTEGIUM RIPARIUM Br. Eur. var. **longinerve** Card. & Thér., var. nova.— A forma typica nervo in acumen longius producto distinctum.

Arkansas: Varner, in water (B. F. Bush, 1898).

Resembles *A. vacillans* Sull. in the long-nerved leaves, but in this species the branch leaves have a short obtuse acumen, while in our moss they are narrowly and acutely acuminate, like the stem leaves.

HYPNUM HALLERI Linn. fil. apud Swartz Meth. Musc. 34.

Labrador: l'Anse-au-Mort (Waghorne, 1894); Cook's brook (Waghorne, 1897). Newfoundland: Middle Arm, on rocks (Waghorne, 1896).

A very distinct species of the subgenus *Campylium*, at once characterized by the very dense tufts, the stems entirely prostrate and divided into pinnate branches, the leaves much crowded, recurved-squarrose from a more erect base, minutely denticulate all around, and with a much shorter point than in the allied species.

HYPNUM CUPRESSIFORME L. var. RESUPINATUM Sch. Coroll. 133. (*H. resupinatum* Wils., Bryol. Brit. 398).

Newfoundland: Chance cove (Rev. A. C. Waghorne, 1891).

This variety, considered by many authors as a distinct species, is characterized by the leaves not falcate-secund, imbricate or homomallous and pointing upward, and the capsule erect and symmetrical or very slightly curved or inclined. It is connected with the type by intermediate forms.

HYPNUM MOLLE Dicks. var. SCHIMPERIANUM Sch., Syn. 775 [ed. 2]. (*H. Schimperianum* Lorentz, Moost. 123, *pl. 5, fig. c*).

Northwestern Montana: in the vicinity of Lake MacDonald, Flathead county (J. M. Holzinger and J. B. Blake, 1898).

Differs from the type by the longer and more slender stems, naked below, and by the leaves smaller and with a shorter acumen.

STENAY and LE HÂVRE, FRANCE.

EXPLANATION OF PLATES II–V.

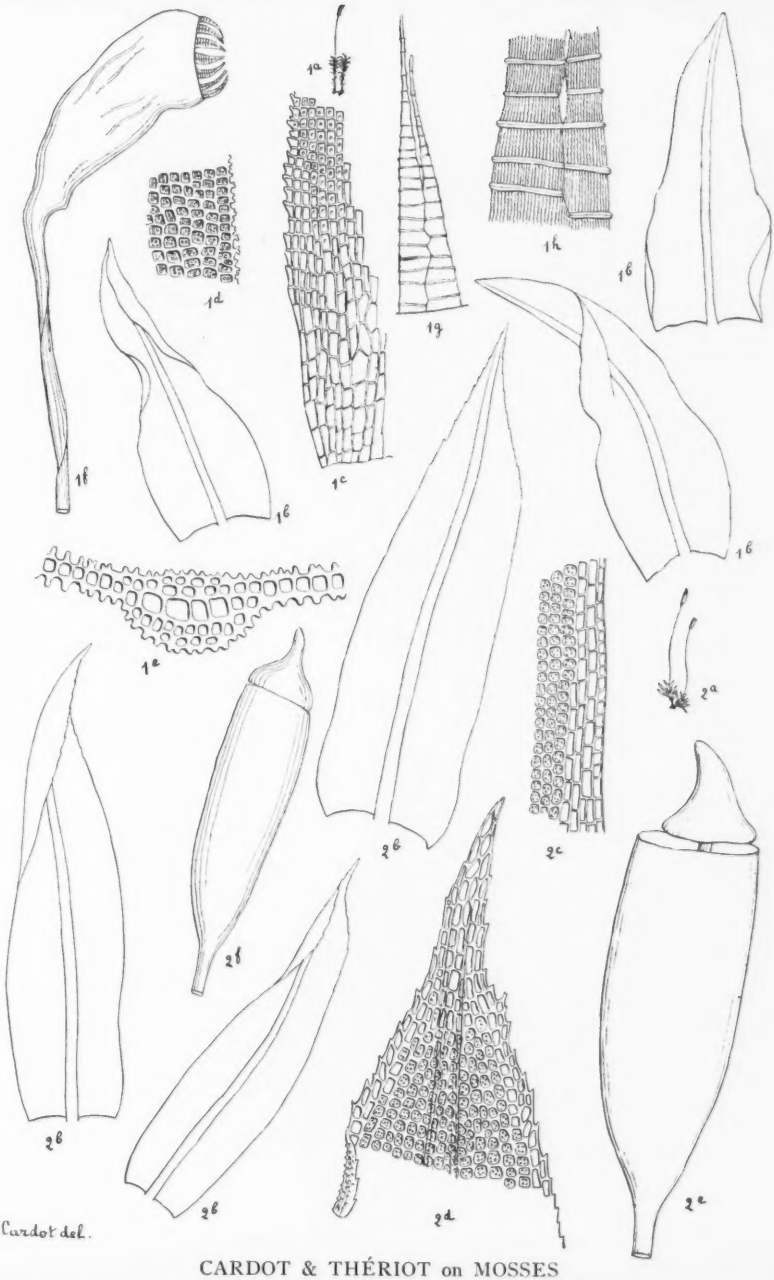
Nachet's objectives 3 and 6, oculars 1 and 3, with camera lucida. All drawings are reduced ¼ in photo-engraving.)

PLATE II.— 1. *Dichodontium Olympicum*. *a*, entire plant, nat. size; *b*, *b*, *b*, leaves × 32; *c*, basal areolation × 135; *d*, marginal areolation in the upper part × 260; *e*, transverse section of the nerve × 260; *f*, capsule ripe and deoperculate × 26; *g*, a tooth of the peristome × 105; *h*, part of the same in the upper part × 285.— 2. *Desmatodon systylioides*. *a*, entire plant, nat. size; *b*, *b*, *b*, leaves × 32; *c*, marginal areolation in the middle × 135; *d*, areolation of the upper part × 135; *e*, capsule ripe × 32; *f*, capsule unripe × 32.

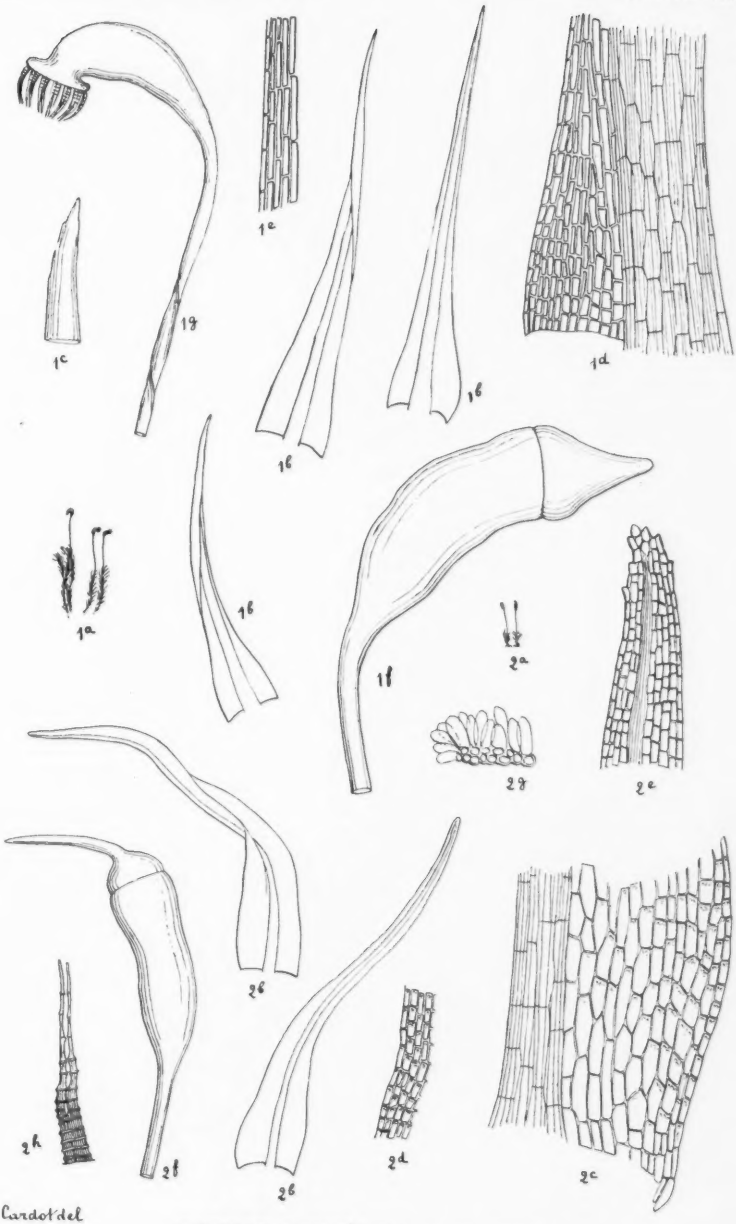
PLATE III.— 1. *Dicranella Howei*. *a*, entire plant, nat. size; *b*, *b*, *b*, leaves × 32; *c*, apex of a leaf × 135; *d*, basal areolation × 135; *e*, marginal areolation in the middle of a leaf × 135; *f*, capsule in moist state × 32; *g*, capsule ripe and deoperculate, in dry state × 32. — 2. *Dicranella laxiretis*. *a*, entire plant, nat. size; *b*, *b*, leaves × 32; *c*, basal areolation × 135; *d*, marginal areolation in the middle × 135; *e*, areolation of the upper part × 135; *f*, capsule × 32; *g*, portion of the annulus × 135; *h*, a tooth of the peristome × 135.

PLATE IV.—1. *Barbula eustegia.* *a*, entire plant, nat. size; *b*, the same × 3; *c*, *c*, *c*, *c*, leaves × 32; *d*, basal areolation × 135; *e*, areolation of the upper part × 135; *f*, external perichætial leaf × 32; *g*, inner perichætial leaf × 32; *h*, capsule × 32; *i*, peristome × 60; *j*, portion of a peristomial tooth × 285. —2. *Grimmia pseudo-montana.* *a*, entire plant, nat. size; *b*, *b*, leaves × 32; *c*, basal areolation × 135; *d*, areolation of the upper part × 135; *e*, transverse section of the leaf in the lower part × 135; *f*, transverse section of a leaf in the upper part × 135; *g*, capsule ripe × 26; *h*, two teeth of the peristome × 135.

PLATE V.—1. *Orthotrichum Idahense.* *a*, entire plant, nat. size; *b*, *b*, leaves × 32; *c*, basal areolation × 135; *d*, areolation in the upper part × 135; *e*, transverse section of a leaf × 135; *f*, capsule ripe and deoperculate, in dry state × 26; *g*, areolation of the capsular membrane in the upper part × 135; *h*, the same, in the lower part, showing a stoma × 135; *i*, two teeth of the peristome × 135; *j*, young calyptra × 26.—2. *Bryum euryloma.* *a*, entire plant, nat. size; *b*, leaf × 26; *c*, marginal areolation in the middle of a leaf × 135; *d*, areolation of the upper part × 135; *e*, capsule in dry state × 15.



CARDOT & THÉRIOT on MOSSES



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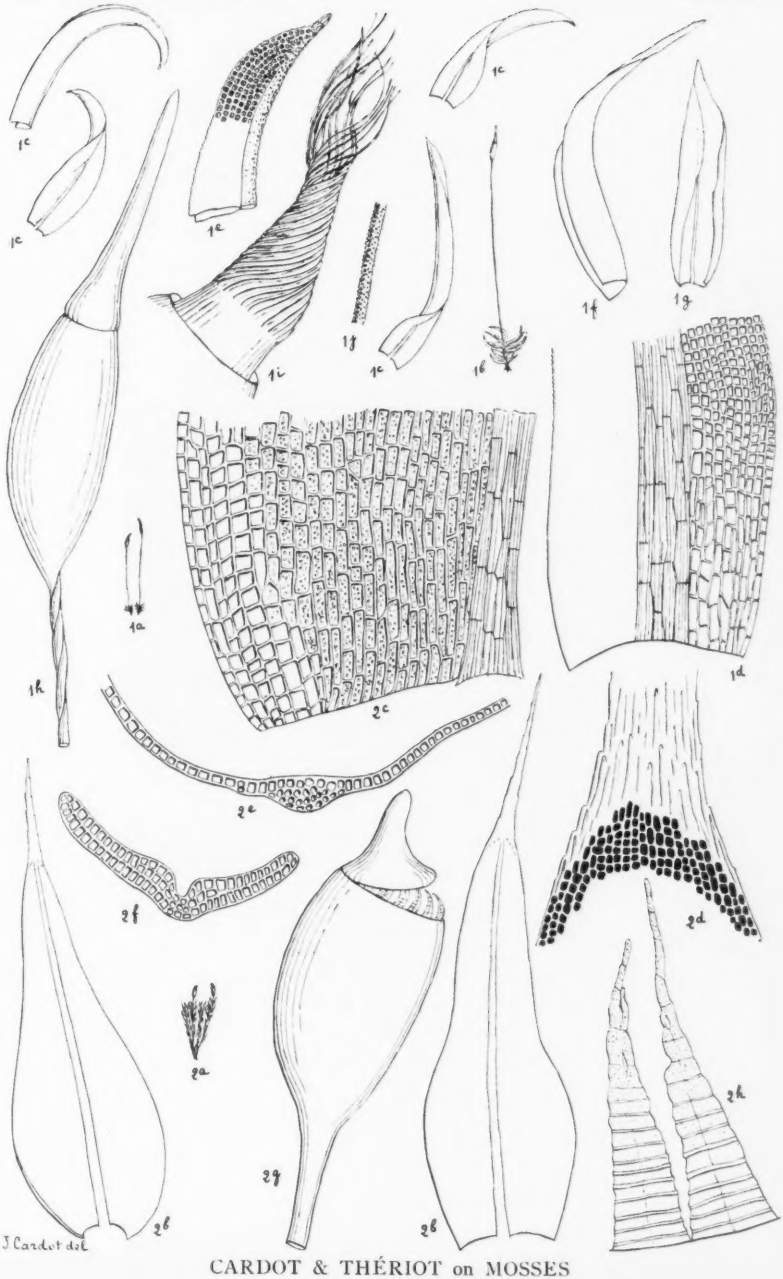

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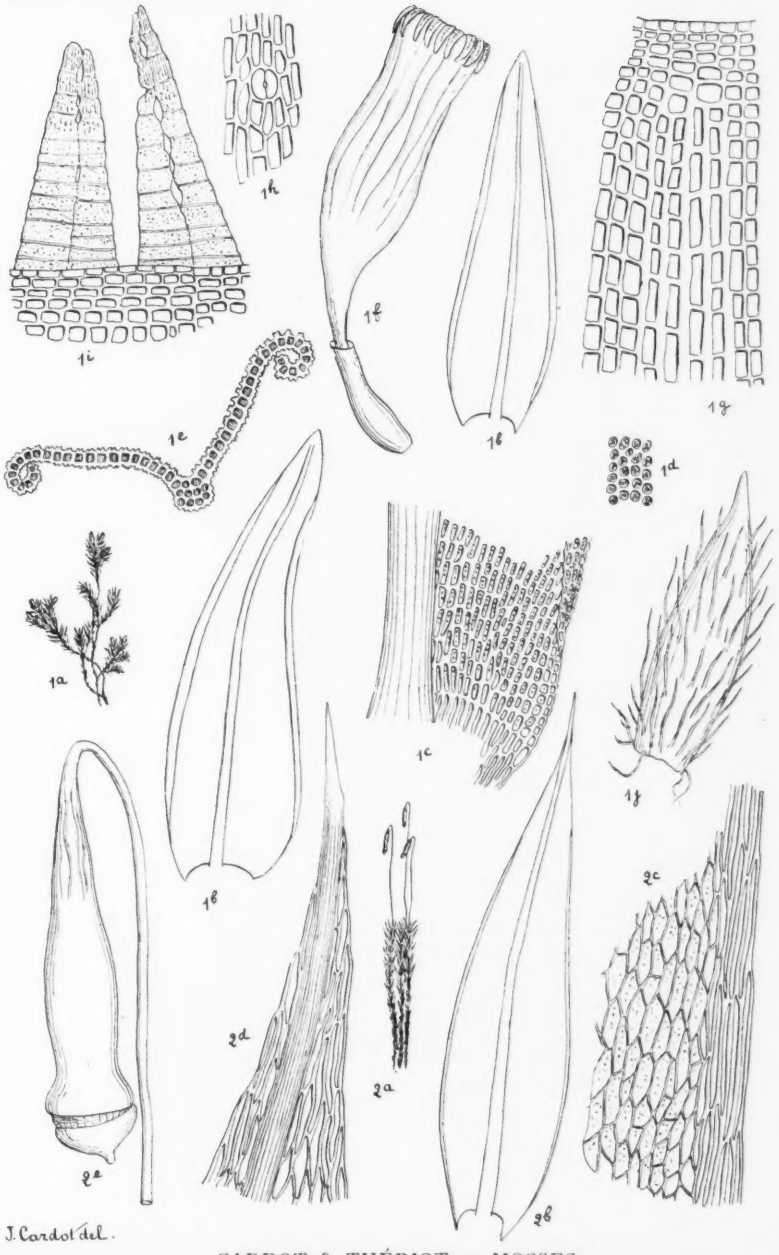

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THE DEVELOPMENT OF THE EMBRYO-SAC IN SOME MONOCOTYLEDONOUS PLANTS.

KARL M. WIEGAND.

(WITH PLATES VI AND VII)

THE material for the following study was prepared in the ordinary way, by fixing in the chrom-aceto-osmic acid solution, imbedding in paraffin, and staining with the gentian-violet-orange combination. Although the development in Canna was found to be nearly normal, that in each of the other two plants showed some very interesting and important variations. Whether these throw any light on the problem of the homology of the embryo-sac can be determined only by more extended study of other plants.

Convallaria majalis L.

THE HYPODERMAL CELL AND ARCHESPORIUM.

The embryo-sac of Convallaria is derived from a hypodermal cell situated at the apex of the nucellus. This hypodermal cell is first discernible as an enlarged oblong or more or less distinctly triangular cell at the apex of the nucellus and directly underneath the epidermis; but can also be distinguished from the adjacent cells by its larger size and more granular contents. Very early in its development a single cell, the so-called "tapetum," is cut off on the side adjacent to the epidermis. This immediately divides by an anticlinal wall into two daughter cells which lie side by side at the summit of the embryo-sac (*fig. 1*).

The nucellus is comparatively broad, and the growth of the archesporium taking place subsequent to the separation of the wall-cell is to a large extent in a lateral direction. To accommodate themselves to this the two daughter wall-cells undergo repeated anticlinal division, so that eight or ten cells are formed, all arranged in the same plane, and forming a plate of tissue just beneath the epidermis (*fig. 2*). The nuclei of

these cells increase somewhat in size until they are noticeably larger than those of the surrounding tissue, but unlike the sporogenous nuclei remain very dense. As the embryo-sac grows larger these cells are all pushed aside, with the exception of the more central ones which persist between the embryo-sac and the epidermis until after fertilization.

The other daughter cell resulting from the division of the primary hypodermal cell constitutes the archesporium. This immediately expands in all directions, partly at the expense of the ordinary tissue. At the time of the first nuclear division, the cell is oblong in shape and occupies a considerable portion of the nucellus. The nucleus during its period of growth passes through stages almost identical with those described for the microsporangial archesporium.[1] The chromatin network changes during synapsis (*fig. 2*) to a spirem ribbon (*fig. 3*), which later segments into the individual chromosomes. Corresponding stages in the nucleus of the pollen-mother cells and embryo-sac archesporium cannot be distinguished structurally; and this similarity is still farther emphasized by the synapsis occurring in each at the same stage in development.

THE FIRST NUCLEAR DIVISION.

Several good preparations of the first nuclear division were obtained, both in the nuclear plate and anaphase stages. In the plate stage the fibers are well marked; indeed the fascicles attached to the chromosomes are especially large and prominent. The spindle, like that of the pollen-mother cell, is rarely pointed at the poles, but is more often truncate (*fig. 4*).

The chromosomes are large oblong bodies arranged on the nuclear plate just as they are in the pollen-mother cell; that is, horizontally with one end directed away from the axis. Simultaneously the outer and inner ends commence to split longitudinally, but in perpendicular planes. In one case the separation is accomplished wholly without the aid of the spindle fibers; in

[1] WIEGAND: The development of the microsporangium and microspores in Convallaria and Potamogeton. BOT. GAZ. **28**: 328. 1899.

the other the fibers seem to accomplish the separation. The former splitting is only partial, while the latter finally divides the chromosome into two V-shaped parts which move at once to the poles through the influence of the spindle fibers. This is therefore a heterotypic division, and similar to the one occurring in the pollen-mother cell. In fact it seems probable that having the spindle alone one could not distinguish the two cases, even after a careful study of the chromosomes themselves. The number of chromosomes was found to be eighteen, and since the number counted in the somatic cells was greater than thirty, it is evident that reduction takes place at this period. During the anaphase of the first division (*fig.* 5) a definite cell-wall is deposited, which divides the original cell into two nearly equal parts.

THE SECOND NUCLEAR DIVISION.

The nucleus in each of the two daughter cells resulting from the first division very quickly divides again, and it so happens that the two spindles are formed simultaneously. No cell-walls are formed after this division, at least not before the embryo-sac is nearly mature. At the stage shown in *fig.* 8 four nuclei are present. The second division spindle was in this case directed longitudinally; therefore in the same plane as the first; but this is not always the case. Sometimes the axis of the spindle is inclined and in fact almost transverse. The position of the spindle, however, seems to be of little importance, since one may find the two daughter nuclei during later stages either one above the other or side by side.

The resting stage between the first and second divisions, like that in the pollen-mother cell, is very short. The V-shaped chromosomes remain distinct and uninclosed by a definite membrane. The spindle quickly forms, apparently from the surrounding cytoplasm, and at the same time the chromosomes are crowded toward the equator where they arrange themselves in a nuclear plate. These spindles were in all cases much less distinct than the first one, and appeared in the earlier stages

shorter and more truncate, while in the anaphase no cell-plate whatever was produced.

The way in which the chromosomes divide could not be positively determined. The segments on entering the nuclear plate, and even while in the plate as seen from the poles, are much curved (*fig. 6*). A side view of the nuclear plate shows a dense mass with projecting arms similar to the corresponding figure in the pollen (*fig. 6*). When the segments move to the poles they are seen to be quite long and straight, and never V-shaped as in the heterotypic division (*fig. 7*). After reaching the pole they at length fuse, and a membrane is formed around them, thus bringing about a truly resting condition again.

It seems scarcely to be doubted that the process here is identical with the second division in the pollen-mother cell. Indeed, every appearance in the one has its almost exact counterpart in the other.

GROWTH AND DEVELOPMENT OF THE EMBRYO-SAC.

The further history of the embryo-sac is very interesting, since it shows some deviations from the ordinary process in both monocotyledons and dicotyledons. The two superimposed daughter cells should probably be considered as constituting the so-called "axial row" in this case (*figs. 6–8*). At least, so far as the nuclei are concerned, they are the equivalents of the two cells first formed in Canna. There is therefore a two-celled axial row instead of a four-celled one, as in Canna and many other plants. It would be expected then that during development the lower cell alone would become the embryo-sac, while the upper would undergo dissolution as in nearly all other cases. This, however, is not the case.

At the time when the spindles of the second division occur, the archesporium as described above is two-celled. No walls are produced by the second spindles, as a result of which each cell now contains two nuclei. This stage is followed by a comparatively long period of growth in which both cells increase several times in size, as do also their nuclei. A large number of

preparations were obtained illustrating this condition and representing all stages up to the next division of the nuclei. As shown in the accompanying figure (*fig. 8*), the upper cell becomes gradually larger and more vacuolate, while the cytoplasm of the lower stains more deeply and fills nearly the entire cell cavity. No cases were observed, however, where one could infer that either cell was in the process of disintegration.

At a period shortly before the opening of the flower further changes occur, the first of which is the immense increase in size of the upper cell. The wall between the two still seems to remain intact, although becoming very thin and delicate. In some cases the wall is so delicate at this stage as to be almost invisible, and may have broken down entirely, in which case both cells would be merged into the general cavity of the embryo-sac, but in later stages two cells are again seen. All of the four nuclei undergo division simultaneously, resulting in the stage with eight nuclei, just as in Lilium (*fig. 9*). In several cases shortly after this two large nuclei were seen fusing near the lower end of the upper cell, while the lower cell contained the distorted remains of three other nuclei. The latter cell was thus apparently already in the process of disintegration. It seems probable that one of the four nuclei originally formed in the lower cell must have ruptured the thin cell-wall and fused with the upper polar nucleus after the normal manner.

In *fig. 10* is represented an embryo-sac just prior to fertilization. At this stage the "egg-apparatus" consists of two synergids and the egg. The former lie close together, with the long axis more or less transverse to the axis of the embryo-sac, and are elliptical in shape, with the wall at the upper end thickened and densely striate. Just below these is the large egg nucleus, separated from the synergids and from the main cavity by very delicate cell membranes which seem to extend completely across the embryo-sac so as to join the lateral walls on either side. Below the egg-apparatus is the very large main cavity of the embryo-sac lined with a thin layer of cytoplasm. In this, near the base, is the large definitive nucleus still showing signs of the

previous fusion of the two polar nuclei. At the base of the embryo-sac are the distorted remains of three antipodal nuclei still separated from the main cavity by a distinct cell-wall. It was impossible to determine whether this had been formed anew, or whether the old perforated wall had simply been repaired.

At the time when the main features of this study of Convallaria were read at the Boston meeting of the American Association for the Advancement of Science, so far as the writer was aware no exactly similar case had been observed. Mann [2] had discovered a cross wall in the embryo-sac of Myosurus, but here the development seems to have been somewhat different; and Strasburger [3] had figured a structure somewhat resembling a cross-wall in the embryo-sac of Allium, although it was mentioned in the text as a plasma-plate. Since that time, however, McKenney [4] in making a careful study of the embryo-sac of Scilla has described a process very similar to that in Convallaria. The archesporial nucleus underwent a period of growth before dividing. The first division showed the reduced number of chromosomes and was followed by a cell-wall. The two succeeding divisions in each daughter cell were not followed by a cell-wall, so that as a result two cells were present, each containing four nuclei. Up to this point the process was similar to Convallaria, but it was further found that only the upper cell took part in the formation of the embryo-sac, and not both as in Convallaria, while the lower cell disintegrated.

The process in Convallaria is strikingly similar to that in Lilium, and is probably to be considered as simply a modification of that method or a transition to it from the ordinary type with two or four cells in the axial row. It differs merely in the possession of a cross-wall, which however partially or

[2] MANN: The embryo-sac of *Myosurus minimus* L. Trans. and Proc. Bot. Soc. Edinburgh **29**: 351. 1892.

[3] STRASBURGER: Die Angiospermen und die Gymnospermen (1879). *Pl. 6. figs. 81–86.*

[4] MCKENNEY: Observations on the development of some embryo-sacs. Contrib. Bot. Lab. Univ. Pennsylvania **2**: [no. 1] 80. 1898.

entirely breaks down before the fusion of the polar nuclei, one of which comes from each cell.

Potamogeton foliosus Raf.

THE HYPODERMAL CELL AND ARCHESPORIUM.

In the earliest stage obtained the hypodermal cell at the apex of the nucellus had commenced its period of growth. No definite form can be ascribed to it at this period, although it is perhaps more often wedge-shaped. Even from the beginning it usually contains more protoplasm than the other cells, a feature which at a later stage becomes still more noticeable.

After a short period of growth this cell divides. The inner daughter cell resulting from the division becomes immediately the archesporial cell (*fig. 14*). The outer daughter cell divides again by an anticlinal wall. Two cells now lie side by side above the archesporium, as is represented in *fig. 12*, which shows a cross-section through the apex of the nucellus. *Fig. 13*, also a cross-section of the nucellus taken from the same inflorescence as *fig. 12*, shows that each of two cells now divides again, so that four daughter cells are formed all in the same plane. This last division may take place either before or after the first periclinal division of the wall-cell, commonly however before. Periclinal divisions in all four cells now begin, so that at length four rows of cells are formed between the archesporium and the epidermis. The process may continue until as many as six layers are produced; and these all persist until the embryo-sac reaches maturity, although often in a more or less compressed condition.

In the anther the hypodermal cell divides into two parts, one being destined to produce the archesporium, while the other after two or three periclinal divisions constitutes, together with the epidermis, the wall of the anther. The stages leading up to the production of the embryo-sac in the ovule are in many respects very similar to those occurring in the young anther. The hypodermal cell here also divides by a periclinal wall into two daughter cells, the innermost of which

becomes the archesporium, while the outer, the so-called 'tapetum,' forms a part of the sporangial wall.

In Rosa[5] and Fagus[6] the epidermis has been found to divide several times by periclinal walls, and thus to form a considerable portion of the tissue between the archesporium and the apex of the nucellus. The unusually large number of cells in this region in Potamogeton at first suggested that the same phenomenon might also be found here; but a careful study showed that no divisions of the epidermis beyond an occasional doubling of individual cells ever take place, and all of the tissue can be easily traced to the primary wall-cell. Moreover, the similarity to the process in the microsporangia is so evident as to require no other explanation.

THE FORMATION OF THE EMBRYO-SAC.

The lowermost cell formed by the first division of the hypodermal cell begins to enlarge at once, and must henceforth be considered as the archesporium. The whole process during the early stages of development is perfectly normal. The archesporial cell soon undergoes division resulting in an upper and a lower cell (*fig. 15*). These probably correspond to the two resulting from the heterotypic division in Convallaria, but the fate of the two cells we shall find is somewhat different either from that in Convallaria or in Canna. The first division is immediately followed by a second nuclear division in each of the daughter cells, but without the formation of a wall between the two nuclei(*fig. 16*). The uppermost cell now shows signs of disintegration, as indicated by the cytoplasm, which becomes more dense and also stains more deeply. The nuciei also lose their definite outline, and finally the whole cell becomes much compressed and flattened against the wall-cells above. In a very short time, indeed, it can be recognized only as a dark cap at the summit of the embryo-sac. Several preparations were

[5] STRASBURGER: Die Angiospermen und die Gymnospermen 14. Jena, 1879.

[6] BENSON: Contributions to the embryology of the Amentiferae. Trans. Linn. Soc. II. Bot. 3: 410. 1894.

obtained showing the various stages of this process with great clearness.

The lower cell on the other hand continues to enlarge. The two nuclei are usually located at opposite ends of the cell and are somewhat larger than those of the surrounding tissue (*fig. 17*). In the next stage observed both of these nuclei had undergone division, so that two were present at each extremity of the embryo-sac (*fig. 18*). At the antipodal end, from this stage onward, a small pouch begins to appear which contains the two lower nuclei and finally all of the antipodal cells. One of the two upper nuclei is now sometimes found slightly below the other, and nearer the center of the embryo-sac; but many other preparations show that this is merely temporary or abnormal, and that before the next stage is completed they are both located together at the apex of the cell cavity (*fig. 19*).

Very soon after the last nuclear division a cell membrane can be seen to form around the two nuclei at the mycropylar end of the embryo-sac, thus enclosing them in a little pouch (*fig. 19*). The membrane constantly grows thicker, until at length it is a distinct wall, and the two nuclei are henceforth entirely separated from the cavity below. This seems to preclude entirely the possibility that a polar nucleus may pass down and fuse with one from the lower group of cells, although the latter remains in the general cavity of the embryo-sac until a much later period.

At a still later stage three nuclei instead of two are to be found in the micropylar enclosure (*fig. 20*). Two of these are small and differ but slightly from those of the surrounding tissue, while the third is much larger and located below close to the membrane. It seems probable that the two smaller nuclei are produced by the division of one of the two original nuclei, and are really to be considered as synergids; while the other and larger one is the egg derived directly from the other nucleus without division.

The two nuclei at the antipodal end of the embryo-sac after the pouchlike extension has commenced to form usually lie one

above the other and are both quite large, each containing a large chromatin mass in the center (*fig. 19*). The lower one now divides into three daughter nuclei, all very much smaller than the parent nucleus, and with the chromatin scattered instead of being aggregated in a ball. These are all to be considered as antipodal cells, and persist in the little pouch until after fertilization. The upper nucleus continues to enlarge somewhat until about the time of fertilization, when it undergoes division followed by a cell-wall, as a result of which one daughter nucleus is inclosed in a cavity at the antipodal end of the embryo-sac (*fig. 21*). This then must be considered as a fourth antipodal cell, since it is one of the four parts of the original lower nucleus. The other daughter nucleus is the polar nucleus, but becomes at once the mother cell of the endosperm, and immediately undergoes division until a parietal layer of endosperm is formed (*figs. 23, 24*). The large antipodal nucleus and those of the endosperm, like the original nucleus from which they sprung, are all large and contain very large central chromatin masses. This, in addition to their position at successive stages, points toward a common origin. The large antipodal nucleus continues to grow for some time and is at length very conspicuous. It is by far the largest in the ovule, and the very large deeply staining chromatin mass may be seen even after the embryo has reached a considerable size.

The nuclei in Potamogeton are all very peculiar, differing from the ordinary type in having the chromatin mostly aggregated in a ball at the center of the cavity, instead of being distributed on the linin network. Although several hundred slides were prepared, none contained spindles in the embryo-sac, and consequently the sequence of the divisions had to be determined by other means. The appearance of such a remarkable process of development, and one so different from those already described, although still strongly suggesting certain features of the process found by recent investigators in related plants, made it very important that every step should be verified as far as possible. For this reason the material was worked over several

times, until the steps became so clear as to leave no doubt in the mind of the writer that the description as given above is correct.

To summarize briefly: the mature embryo-sac consists of an egg and two evanescent synergids, each without a cell-wall of its own, but all contained within a pouchlike cavity separated from the general cavity by a delicate wall. One synergid usually disappears before fertilization. Next below is a large cavity containing the endosperm nucleus, and later the endosperm, derived without fusion from the lower polar nucleus. At the base are the four antipodal cells, three of which are very small and chromatic, and are descendants of the same nucleus, while one is very large and together with the polar nucleus is derived from another parent. The antipodals are separated from the main cavity by a membrane formed at the time of separation of the polar nucleus and the antipodal cell. The endosperm even after fertilization never becomes more than a parietal layer (*fig. 24*).

The investigation of plants of the same and nearly related orders has shown that the occurrence of the large antipodal nucleus is not a peculiarity of Potamogeton alone, but is characteristic of a whole group of Monocotyledons. Schaffner[7] found that in Sagittaria the development was normal up to the formation of the two synergids, egg, and three minute antipodal cells. He then found that the two polar nuclei fused in the ordinary way, after which the definitive nucleus underwent division. This division was always followed by a transverse wall enclosing one of the daughter nuclei in a chamber at the base; and this was the one which became so large at a later period. Sometimes several were found, thus showing that the large nucleus had divided at least once or twice. From the other daughter nucleus was produced the endosperm. The structure in question was therefore thought to be an endosperm nucleus, rather than an antipodal cell as in Potamogeton.

[7] SCHAFFNER: Contribution to the life history of *Sagittaria variabilis*. BOT. GAZ. 23: 252. 1897.

In Naias and Zannichellia Campbell[8] found an axial row of two or three cells the lower of which alone became the embryo-sac. The development was normal up to the point where the polar nuclei were formed. The free egg-nucleus and synergids and the minute antipodal cells were very characteristic; but no fusion of polar nuclei was observed, and he doubts if it ever occurs. The enlarged basal nucleus is always present from this stage onward, but is not separated by a wall from the main cavity as in Potamogeton and Sagittaria. Campbell believes with Schaffner that this is a product of the first division of the definitive nucleus, but also admits that it may be the lower polar nucleus alone, while the upper has gone to form the endosperm.

FERTILIZATION.

The stages representing the various steps in the process of fertilization are rarely met with in this plant. Several good preparations were obtained, however, and these will form the basis of the following description.

The pollen tube enters the embryo-sac through the micropyle at a point directly behind the egg. In its course it passes close to the partially disintegrated synergid, but the tube is quite slender and scarcely inflated after entering the embryo-sac, thus differing decidedly from Sagittaria, in which Schaffner described the inflation as very marked.

The two sperm nuclei were last noted in the mature pollen grain where they were both inclosed in the same cell-wall. They remain united even during their trip down the pollen tube to the embryo-sac and enter the egg together. Fusion of the egg and sperm nucleus was not observed. The stage immediately preceding this was found however, and is figured in *fig. 22*. Here the egg is easily recognized, and lying in close proximity to it, indeed even touching it, are the sperm nuclei. In reality only one actually touches the egg nucleus. The other lies at the side or even at the back of the first, and is already in the process of

[8] CAMPBELL: A morphological study of Naias and Zannichellia. Proc. Calif. Acad. Sci. II. 1:1. 1897.

disintegration. It seems therefore that in this case the two sperm cells never separate. At this stage the wall which separates the egg from the rest of the embryo-sac is prominent, and can easily be seen to inclose the synergids as well. Campbell found both sperm nuclei entering the embryo-sac in Naias but only one in Zannichellia. Schaffner found that in Sagittaria one always remained in the pollen tube.

THE EMBRYO.

The classical investigations of Hanstein[9] and Famitzin[10] on the development of the young embryos in both monocotyledons and dicotyledons have made us familiar with the process in a large number of plants. The work of later students has only gone to confirm the results reached by these investigators, at least as regards general features. However, the results obtained from certain monocotyledons by Schaffner and later by Campbell seem to be at variance with those above mentioned; and as bearing upon this point Potamogeton becomes of interest.

In Potamogeton the fertilized egg nucleus remains for a very short time in the resting condition, perhaps it divides immediately, but lack of spindles in the young embryos made it impossible to determine this. Immediately after the first division, the basal cell undergoes a change whereby it becomes gradually larger until a size several times the original is reached. At this stage the cell is a very striking object (*figs. 24, 26*). The very large vacuole, which soon appears, at length forces the nucleus to the bottom of the cell where it henceforth remains, while the nucleus itself undergoes considerable enlargement. Just behind this large nucleus of the basal cell, one can often see a synergid, even as late as the several-celled stage of the embryo.

The basal cell never undergoes division, but on the contrary remains for a long time in its enlarged condition attached to the end of the embryo-sac. But sometimes during the later stages

[9] HANSTEIN: Die Entwickelung des Keimes der Monokotylen und Dikotylen. Bonn, 1870.

[10] FAMITZIN: Embryologische Studien. Mém. de l'Acad. Imp. Sci. de St. Petersb. VIII. **26**:—. 1879.

of development it may, together with the embryo, become entirely detached, so that the whole mass is then free (*fig. 26*). The wall increases slightly in thickness, and is always thicker than any other wall in the young embryo.

The first division of the egg is soon followed by a second and later by a third. The embryo then consists of a row of four cells of which the three upper have nearly the same size. Occasionally only three cells are present at this stage, but the four-celled stage predominates. The next division is vertical, and in the uppermost cell (*fig. 25*). This is again followed by one or two more oblique walls, thereby dividing the terminal cell into several sectors, each extending from the basal line to the periphery. Periclinal and anticlinal walls form successively in the different sectors, as a result of which the upper cell soon becomes a mass of tissue (*fig. 26*).

Meanwhile divisions have occurred in the next lower cell. This first formed an oblique wall, after which several divisions took place in various directions. The third cell from the apex has divided once or perhaps twice by vertical walls. The embryo now is nearly spherical, a fact which makes it very difficult to trace the development farther with the idea of determining just what portions of the mature embryo are derived from the various primary cells. The oldest stage at which one can with certainty distinguish the four original cells is shown in *fig. 26*.

The subbasal cell has here undergone a transverse as well as two vertical divisions. No further divisions took place in this cell, and owing to this fact there is little difficulty in recognizing the tissues arising from the subbasal cell even in the half-grown embryo. The eight cells remain undivided at the base of the embryo where they form a narrow neck or stalk; in other words they together with the basal cell form the true suspensor (*fig. 27*).

The fate of the other two cells is immediately lost. It can be inferred from their position that the cotyledon arises from the upper cell and the axis from the subapical. We cannot be

far wrong in making this interpretation. The half-grown embryo shown in *fig. 27* was the oldest stage obtained. At this time only the epidermis was differentiated, while the plerome is scarcely distinguishable. At the upper end of the figure may be seen the cotyledon; and at one side the plumule, arising in a depression at the apex of the hypocotyl.

Schaffner and Campbell both find that no division takes place in the enlarged basal cell after its formation. There is certainly none in Potamogeton. Probably the observation of Hanstein that such a division does take place in Alisma was inaccurate. That such a division does occur in some monocotyledons, however, is a well established fact as shown by Coulter[11] in his studies of Lilium. In this plant the basal cell undergoes both longitudinal and transverse divisions. The process in Potamogeton does not differ essentially from that in Sagittaria and Naias, as given by the two authors cited above. The subbasal cell in Naias divides by transverse walls into three instead of two cells, of which the upper forms several cells, while the lower remains undivided. In Sagittaria the subbasal cell divides also once more than in Potamogeton, and the uppermost daughter cells here again form considerable tissue.

Canna Indica L.

THE HYPODERMAL CELL AND ARCHESPORIUM.

Canna represents still a third type of the monocotyledonous embryo-sac, differing in method of development from Lilium Convallaria, and also from Potamogeton.

The hypodermal cell very soon divides into two parts by means of a periclinal wall (*fig. 29*). The upper cell then by repeated anticlinal division rapidly forms a layer of about nine cells directly above the future embryo-sac. This layer together with the epidermis constitutes the wall of the sporangium, and remains unchanged until finally displaced by the embryo-sac beneath.

[11] COULTER, J. M.: Contributions to the life-history of *Lilium Philadelphicum*—The embryo-sac and associated structures. BOT. GAZ. **23**: 413. 1897.

Meanwhile the lower of the two cells formed by the first division of the hypodermal cell has undergone considerable growth. It rapidly becomes several times its original size, and extends nearly to the base of the nucellus; but the increase in breadth is not so great. Just previous to the first division of its nucleus the cell is unusually long and narrow, but is completely filled with cytoplasm (*fig. 29*).

The cell gradually becomes longer and longer until at length a division takes place whereby two daughter cells are formed (*fig. 31*). After a short time both of these daughter cells divide again simultaneously. As a result we have an axial row of four cells reaching from the base to the apex of the nucellus (*fig. 32*). In the upper three cells a change is noticed almost at once, whereby the cytoplasm becomes denser and darker, the nuclei less chromatic, and the cells in fact show evident signs of disintegration (*fig. 33*). The lower cell by its continued growth gradually compresses the other three, which very soon are all crowded into a small disorganized mass in the micropylar region (*fig. 34*). A large number of sections was obtained showing all stages of this process in the plainest manner. The lowermost cell alone finally takes part in the formation of the embryo-sac. The process in Canna, therefore, is exactly in accord with that in the Iridaceæ, Rosaceæ, Polygonaceæ, and many Ranunculaceæ and Liliaceæ as described by Strasburger and others.

Owing to the extremely narrow cavity and small nuclei, the changes within the embryo-sac are very difficult to follow. Humphrey[12] has already given a full discussion of the literature on the embryo-sac of Canna; and also the results of his own investigations on the same plant. In this case the antipodal cells were not discovered, and he came to the conclusion, as did also Guignard[13] that these cells although always formed must disintegrate immediately.

[12] HUMPHREY: The development of the seed in the Scitamineæ. Annals of Bot. 10: 1. 1896.

[13] GUIGNARD: Recherches sur le sac embryonnaire des Phanerogames Angiospermes. Ann. Sci. Nat. Bot. VI. 13: 136. 1882.

From the material at hand it appears that a short time after the last division in the axial row, the primary nucleus of the embryo-sac, *i. e.*, of the lower cell, divides, and one of the daughter nuclei passes to each end of the already much elongated cavity. The spindles representing the latter division were not obtained, but several cases were found where there were two nuclei at each end of the embryo-sac, and still others where there were four (*fig. 34*). One or two sections showed the three antipodals, two synergids, and the egg; while near the center of the cavity was a very large nucleus, apparently the definitive nucleus of the embryo-sac. The fusion of the polar nuclei was therefore not observed, but probably took place as indicated by the two nucleoli and cross line in *fig. 35*. Just previous to fertilization the egg-apparatus was found to be separated from the main cavity by a delicate membranous wall, and to consist of two very small partially disintegrated synergids located very near the micropyle, and a much larger egg nucleus suspended some distance below, as in *fig. 35*. At this stage the antipodals are often in an advanced stage of disintegration, and are more or less clearly separated by a delicate membrane from the cavity above.

Canna differs from Convallaria, therefore, principally in the embryo-sac being formed from one cell of the axial row, and one element of the division into four of the mother nucleus. In the latter plant the whole axial row and all four elements of the division of the mother cell go to form the embryo-sac.

THE NUCLEAR DEVELOPMENT.

At a very early stage the nucleus of the archesporial cell passes into the condition of synapsis, in which as usual the linin is massed together at one side of the nuclear cavity. After a time indications are seen of the gradual loosening of the knot, with a simultaneous migration of the spiral coils to the more distant parts of the nucleus. The nucleolus here, as in Convallaria, is seen to remain intact during the whole process. It stains much deeper with the gentian-violet than does the chromatin,

and can therefore be readily distinguished. The spirem itself is composed of comparatively few turns of the rather broad chromatin thread, and is made up of alternate segments of chromatin and linin (*fig. 29*). The nucleus lies imbedded in the cytoplasm, which at this stage completely fills the cell cavity. It is now very large, and several times the size of those of the adjacent vegetative cells, and from it numerous radiations extend into the surrounding cytoplasm.

The nuclei and chromosomes in Canna are so small that little could be done toward working out the segmentation of the latter. Some features of the nuclear division, however, may be noted.

All of the nuclei in this plant possess a true nucleolus, as in Convallaria, and a very meager linin net-work on which the small amount of chromatin is unequally distributed. In the vegetative nuclei at the time of division the chromatin becomes aggregated into six spherical masses lying just beneath the membrane, and the nucleolus at the same time disappears. The spindle now forms, and the ordinary process of division assures six daughter chromosomes for each resulting nucleus. This count was made many times with great ease, owing to the small number of segments, and always with the same result.

When the archesporial nucleus has reached its limit of growth the chromatin of the spirem ribbon seems to become aggregated into a number of globular masses, as in the vegetative nuclei, except that the number in many cases seems to be more than six. Only two spindles were found representing the heterotypic division, and these both showed the globular daughter segments on their way to the poles (*fig. 30*). The four counts here made gave in every case the number as six, instead of three as one would expect after reduction. The spindles of the second division both occur at the same time, and one or two sections containing these were also obtained (*fig. 31*). They were all in the nuclear plate stage, and here the number was actually three; but each chromosome seemed to be composed of two parts, one of which was located directly above the other

and more or less completely joined to it. The most plausible explanation for this seems to be that the segmentation for both divisions was nearly or quite completed before the formation of the first spindle, and that when they appeared on the nuclear-plate of the second spindle the segments had come together in pairs only to be separated again on going to the poles. No true resting stage seems to intervene between the two divisions. The above results are especially interesting, since three for the reduced number of chromosomes is one of the smallest so far found in plants. The later divisions in the embryo-sac were not observed. The spindle seems to be formed simply by the elongation of the kinoplasmic mass, no multipolar condition being noticed, and the mature spindle is long and slender but usually with obtuse poles. After each division a distinct membrane is deposited at the cell-plate, thus forming the axial row of four cells. The resting nuclei often show very distinct radiations from the nuclear membrane; especially is this the case with the lower one which now commences another period of growth before division in the embryo-sac.

SUMMARY.

Convallaria.—The hypodermal cell divides into an upper and a lower cell, of which the inner cell becomes the archesporium and the upper forms part of the wall. This is also the case in Potamogeton and Canna.

The stages of the growth and development of the archesporial nucleus are identical with those of the nuclei of the microsporangial archesporium.

The first division of the archesporial nucleus is the heterotypic division and corresponds to the first pollen-mother cell division in every respect.

The two spindles accompanying the second division are formed simultaneously. In appearance this division is identical with the second pollen-mother cell division and quite different from either the vegetative or heterotypic. A transverse division of the chromosomes could not be demonstrated.

Only the heterotypic division is followed by a cell-wall, and thus an axial row of two cells is formed each containing two nuclei.

Shortly after anthesis the transverse wall disappears and the four nuclei all divide simultaneously, producing four daughter nuclei at each end of the embryo-sac. The endosperm nucleus is formed by the fusion of one nucleus from each group. After the transverse wall is destroyed, therefore, the process is the same as in Lilium.

The number of chromosomes in the vegetative nucleus is about thirty-six. During the heterotypic and so-called "reducing" divisions eighteen may be counted. The apparent reduction therefore takes place prior to the first division of the archesporium.

Potamogeton.—The first division of the archesporial nucleus is followed by a cell-wall, but the second is not; so that an axial row of two cells, each containing two nuclei, is produced as in Convallaria.

The lower cell forms the embryo-sac, while the upper disintegrates.

Four nuclei are formed in the lower cell; the two at the upper end are at once enclosed by a cell membrane, and from them develop the two evanescent synergids and the egg.

The lower remain free. From one of these all three of the small chromatic antipodals are probably formed. The other divides, forming the fourth antipodal cell and the polar nucleus with a cross-wall between the two. The polar nucleus becomes the endosperm nucleus without fusion.

The mature embryo-sac contains two small synergids and a large egg nucleus enclosed by a wall near the micropyle; a very thin parietal layer of endosperm; and four antipodal cells enclosed by a transverse wall at the lower end of the embryo-sac, of which three are very small and one is very large.

The nuclei of Potamogeton are peculiar in having most of the chromatin aggregated in a ball at the center of the cavity.

At the time of fertilization the two sperm nuclei lie together near the egg nucleus, but only one is really in contact with the latter.

The fertilized egg-cell undergoes at first three divisions, forming a row of four cells. The terminal cell and the one next below give rise to the greater part of the embryo. In the subbasal cell only one transverse and two vertical divisions ever occur, and the cells thus formed together with the very much enlarged basal cell form the suspensor.

Canna.—The heterotypic division is also the first division of the archesporial nucleus, and is followed by a transverse wall.

The second divisions occur simultaneously and are also followed by cell walls. These form an axial row of four cells.

The lower cell alone gives rise to the embryo-sac; the other three finally disintegrate and disappear. The further development is quite normal.

The nuclei of Canna are more nearly like those of Convallaria than Potamogeton. They have a true nucleolus and no central chromatin mass.

The number of chromosomes in the vegetative divisions is six. When passing to the poles at the heterotypic division there were still six; but later the second division showed only three as the reduced number. Probably the segmentations for both divisions occur during the prophase of the heterotypic division. This number is one of the smallest yet found in vegetable tissue.

CORNELL UNIVERSITY.

EXPLANATION OF PLATES VI AND VII.

Figures 1–11. *Convallaria majalis* L.

FIG. 1. A vertical section through a young ovule, showing the epidermis, archesporial cell, and two of the wall-cells between; the archesporial nucleus is in the resting stage.

FIG. 2. The same at a later stage; the wall-cells have undergone further division, and the archesporial nucleus is in synapsis.

FIG. 3. The archesporial nucleus in the spirem stage; the ribbon contains small denser portions of chromatin.

FIG. 4. Nuclear-plate stage of the first or heterotypic division of the archesporial nucleus; the chromosomes appear +-shaped, as in the pollen mother-cell.

FIG. 5. Anaphase of the same division; the V-shaped segments have reached the poles, and the cell-plate is forming.

FIG. 6. The nuclear plate stage of the second or so-called "reducing" division; the chromosomes are arranged very differently; between the two spindles is the wall formed during the previous division.

FIG. 7. Anaphase of the same division.

FIG. 8. A later stage showing the four nuclei thus formed.

FIG. 9. Each of these nuclei now divides forming four at each end of the embryo-sac; the cross-wall has disappeared.

FIG. 10. The mature embryo-sac ready for fertilization; over the apex is the epidermis and the remains of the other wall-cells; the egg-apparatus consists of the large egg nucleus and two striated synergids; at the base are the disorganized antipodal cells enclosed by a cell wall, and above is the endosperm nucleus.

FIG. 11. A spindle from the vegetative tissue, nuclear-plate stage; the chromosomes extend in all directions.

Figures 12–27. *Potamogeton foliosus* Raf.

FIG. 12. A cross section of the apex of the nucellus, showing at the center the two wall-cells lying above the archesporium.

FIG. 13. Same in the four-celled stage.

FIG. 14. Vertical section of the nucellus, showing the archesporial cell with resting nucleus, and one wall-cell above.

FIG. 15. The axial row of two cells; the cross-wall was formed after the first or heterotypic division of the archesporium.

FIG. 16. Same, later stage; the "reducing" division is not followed by a cell-wall.

FIG. 17. The lower cell developing into the embryo-sac; the upper cell forms a crushed mass above.

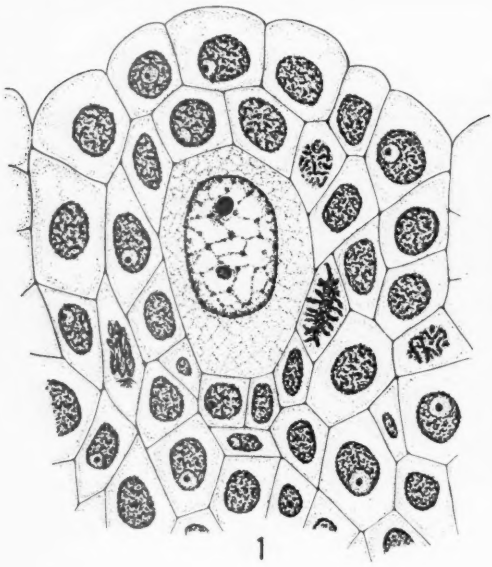
FIG. 18. Same, but each nucleus has divided again.

FIG. 19. Same, with a wall forming just below the two upper nuclei, separating them from the cavity below.

FIG. 20. The young embryo-sac with the large egg and two small synergids enclosed by a cell-wall, three small antipodal cells at the base and a very large nucleus above.

FIG. 21. Same, slightly older; the large nucleus has divided into a polar nucleus above and a large antipodal nucleus below separated by a cell-wall: the former becomes immediately the definitive nucleus.

FIG. 22. Egg apparatus showing a stage in fertilization; the two sperm nuclei lie near the egg, and one synergid above is in the process of disintegration.



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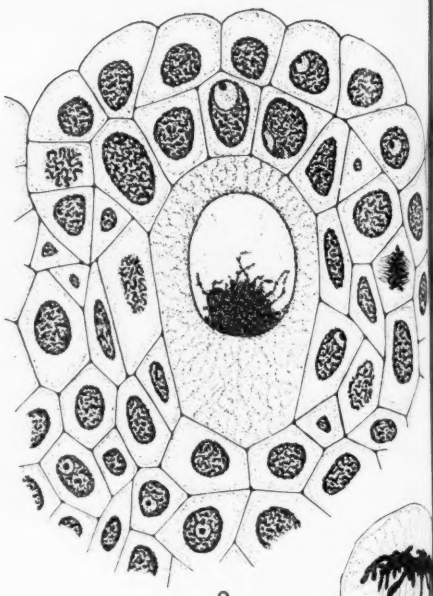

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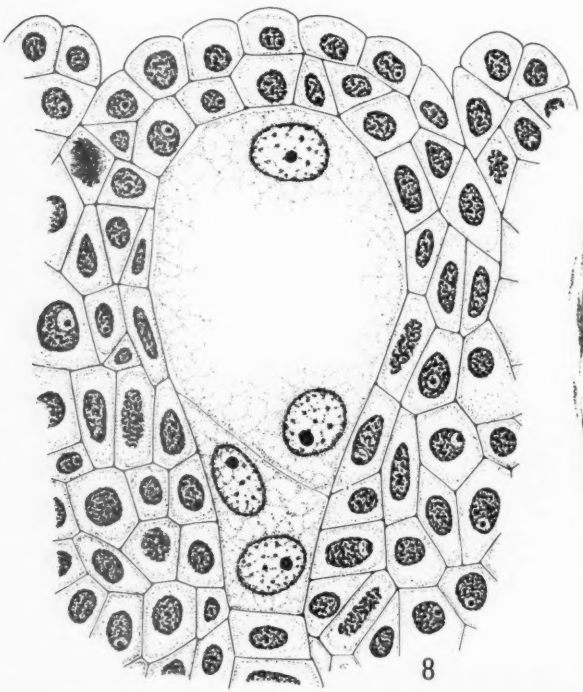

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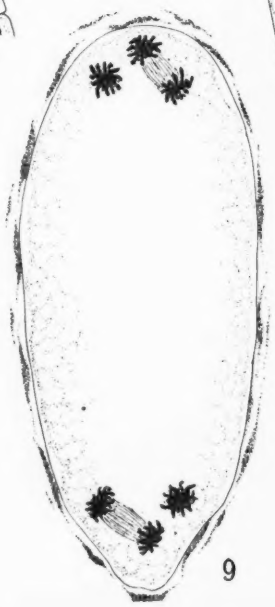

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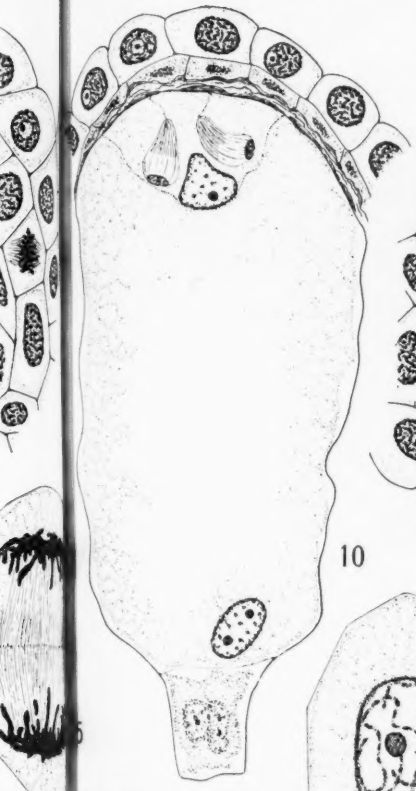

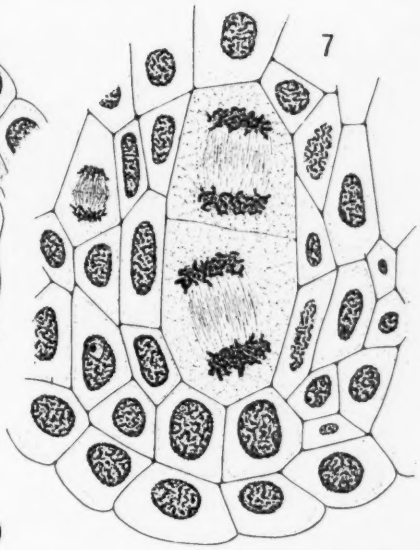

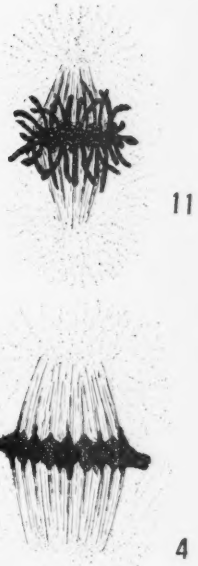

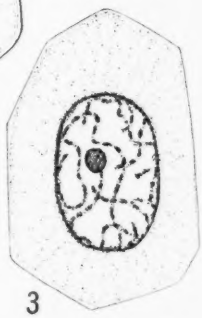

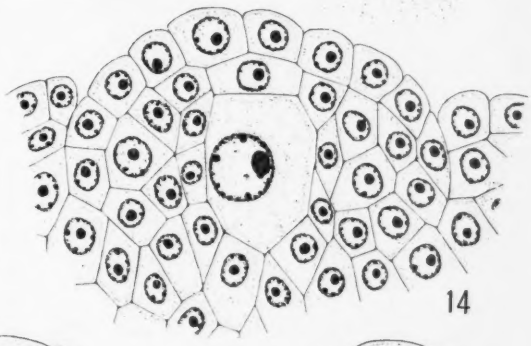

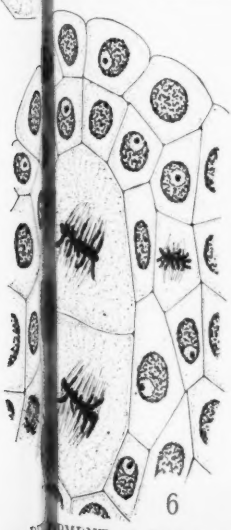

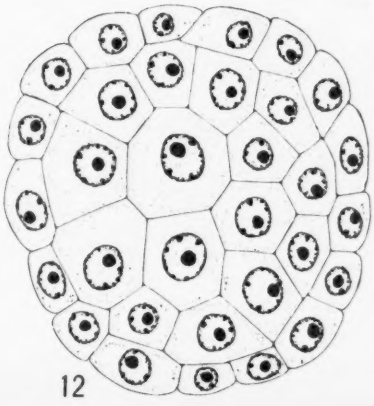

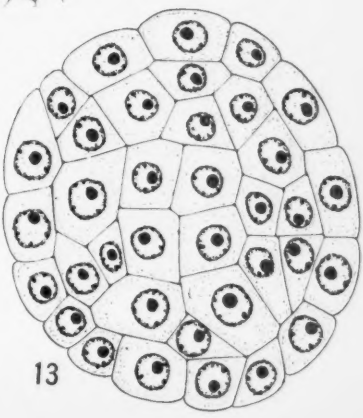

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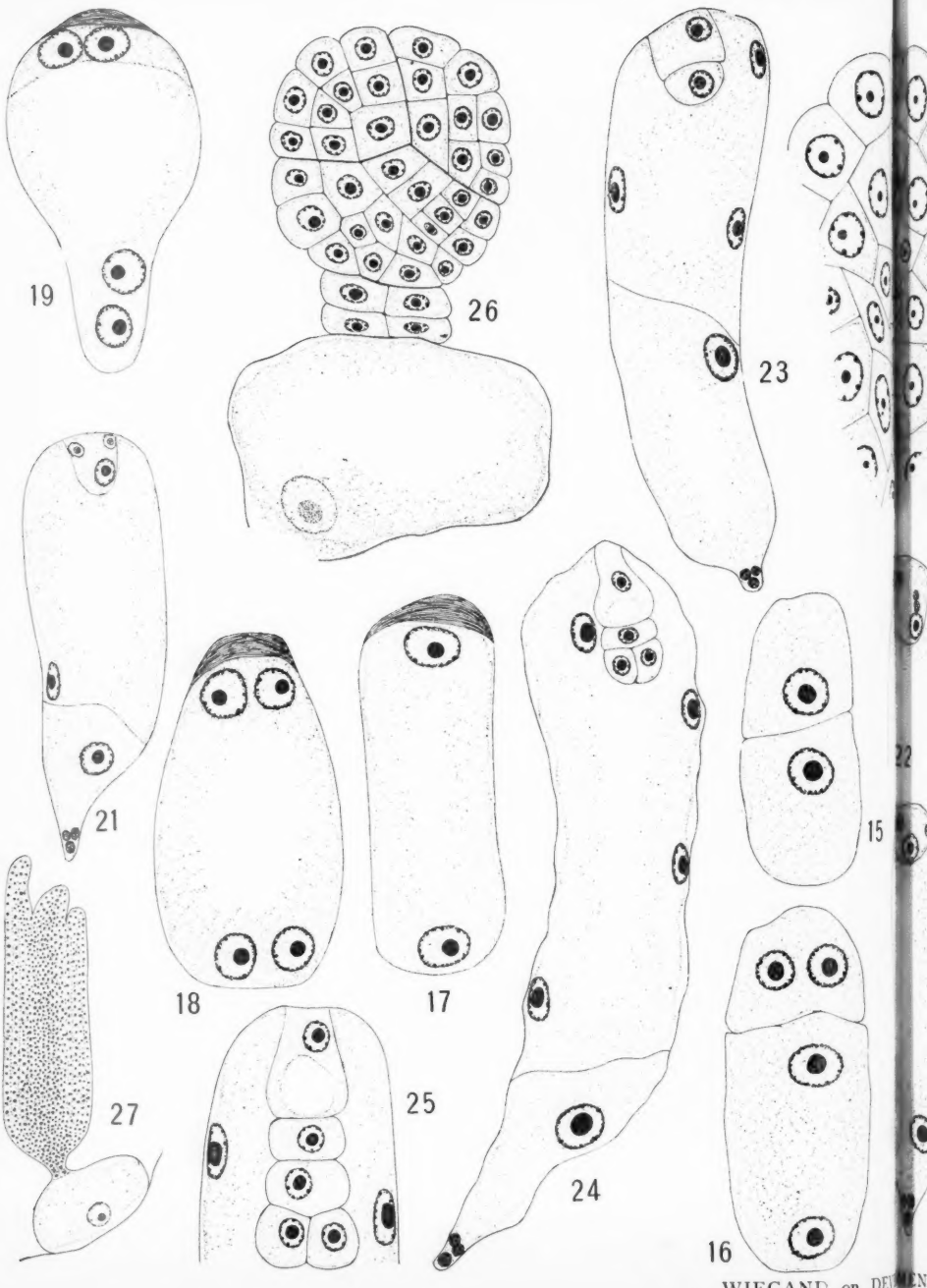
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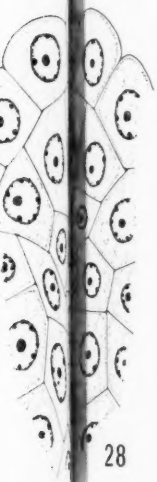
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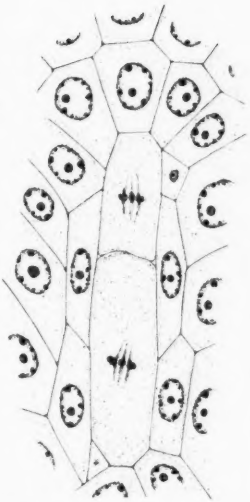
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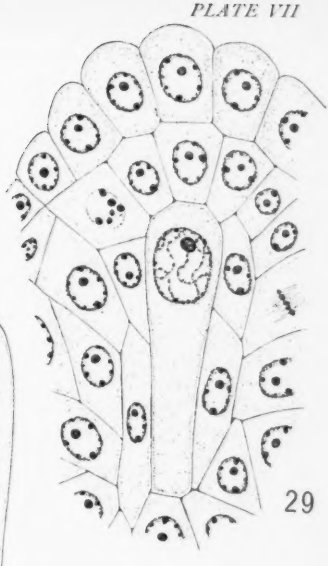
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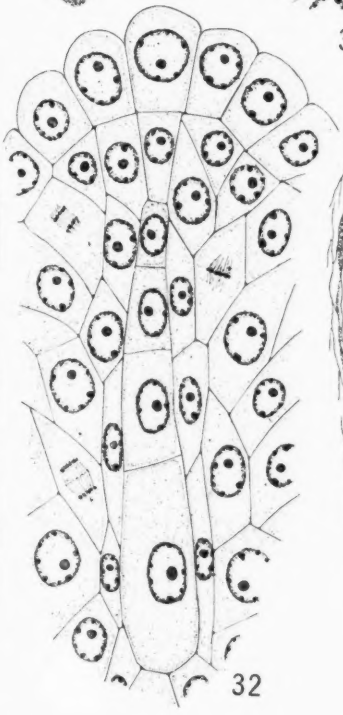
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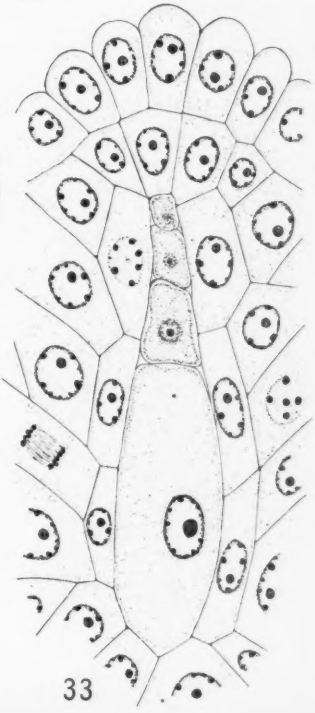
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FIG. 23. The embryo in the two-celled stage; below are three endosperm nuclei and the antipodal cells; this is an abnormal case in which the cross-wall was formed up near the center of the embryo-sac.

FIG. 24. A complete embryo-sac containing a young embryo in which the first oblique wall is in the third instead of the fourth cell.

FIG. 25. A young embryo showing the first oblique wall in the fourth cell as is normally the case.

FIG. 26. The embryo at a later stage; the basal cell has become much enlarged; the subbasal cell forms the remainder of the suspensor, four cells only are here shown; the heavy line through the embryo separates the apical from the subapical cell, and in the former the oblique wall can also be distinguished; the other divisions are irregular.

FIG. 27. The oldest embryo obtained; the basal cell and the derivatives of the subbasal cell still persist; the cotyledon and plumule are differentiated as is also the central cylinder.

Figures 28–35. *Canna Indica* L.

FIG. 28. A vertical section through the nucellus showing the hypodermal cell slightly larger than those of the surrounding tissue.

FIG. 29. Same at a later stage; the hypodermal cell has given rise to the archesporial cell and to a primary wall-cell which in turn has divided into three or four daughter cells; the archesporial cell is already much enlarged and the nucleus is in the spirem stage.

FIG. 30. The first or heterotypic division of the same nucleus in metaphase; six segments in each group may be counted.

FIG. 31. The second division of the archesporial nucleus in the nuclear-plate stage; three chromosomes only are here present; the cross-wall was formed during the previous division.

FIG. 32. The axial row of four cells; the central cross-wall was formed at the heterotypic division, the upper and lower at the second division.

FIG. 33. The axial row with the three upper cells in the process of disintegration; the lower is growing to become the embryo-sac.

FIG. 34. The embryo-sac showing two synergids and the egg nucleus at the upper end, and three antipodals with the polar nucleus at the base; the upper polar nucleus has traveled part way down the lateral wall.

FIG. 35. Same at a later stage; the egg-apparatus is inclosed by a delicate membrane as are also the disintegrating antipodals; the two polar nuclei have fused to form the definitive nucleus.

BRIEFER ARTICLES.

SOME OBSERVATIONS ON APPLE TREE ANTHRACNOSE.

(WITH TWELVE FIGURES)

For several years past the apple orchards of the Pacific northwest, including western Oregon, Washington, and British Columbia, have suffered seriously from the attacks of a fungous disease which has been known locally as "canker," "dead spot," or "black spot."

Although of considerable economic importance, the disease seems to have been entirely overlooked by mycologists, and nothing of importance concerning its nature has been recorded. When it was announced by Mr. Paddock, of the New York Experiment Station at Geneva, that *Sphaeropsis malorum* the cause of the well-known "black rot" of the apple and quince, is also the cause of the bark disease of apple trees, it was hoped that his discoveries would explain the cause of the similar western disease, but only a cursory examination was needed to show that this is not the case. Recently, with Mr. Paddock, I have had the privilege of comparing the two diseases with the result that we were both convinced that they are entirely distinct.

In deciding to ignore the term "canker," the most commonly used of the local names which have been applied to the disease, and in proposing for it the name of *apple tree anthracnose*, I hope to avoid confusion in the designation of the disease in the future. The term canker is most commonly used in European works on plant diseases to designate injuries to the bark caused by the various species of Nectria; and in the eastern United States it has been applied by Mr. Paddock to a somewhat similar disease of apple bark caused by *Sphaeropsis malorum* Peck. The term anthracnose, while it has perhaps no definite botanical significance, seems appropriate from the fact that the fungus which causes it, and for which we here propose the name *Gloesporium malicorticis* is closely related to numerous other fungi of economic importance which have quite generally been designated as anthracnoses.

Apple tree anthracnose attacks principally the smaller branches—those under two or three inches in diameter—although it also occurs

upon the larger ones. It appears first in the fall, soon after the autumn rains begin, as small, irregular, brown, sometimes slightly depressed, areas of the bark. During the fall and winter months it spreads but slowly, but with the advent of warmer weather in spring, growth takes place rapidly until the disease has invaded an area sev-

FIG. 1. FIG. 2.

eral inches in diameter. Such areas under observation at Corvallis, Oregon, the past season cease to enlarge late in May, and early in June the first evidence of spore formation was seen. At that time the diseased areas were dark brown in color, markedly depressed, and in most instances limited by ragged, irregular fissures which separated the dead from the surrounding living tissues (*figs. 1, 2*). These dead spots vary in size from those not more than one half inch in diameter to extensive areas two or three inches wide by six or eight inches long. Occasionally a single area completely girdles a branch, thus killing at once its distal portion ; but more commonly only a dead spot occurs,

FIG. 3.

from which in the course of a few months the bark sloughs off, leaving an ugly wound which requires several years to heal. When these wounds are at all numerous the branches are exceedingly rough and disfigured, and are also greatly weakened.

Early in June the first acervuli were observed. They appeared as small conical elevations of the epidermis, and were scattered irregularly over the diseased area. By the end of June these elevations had increased considerably in size, and in a few instances the overlying epidermis had been ruptured so as to expose the cream colored conidial mass. Material collected at that time and taken by me to Cornell University, where it was examined about the middle of July, revealed the presence of a few conidia, none of which, however, could be induced to germinate. In material which was collected in July, but which was not examined until early in October, the conidia were more abundant, but in dilution cultures in potato-agar only two spores were observed to germinate. However, material which was collected at Corvallis, October 4, and which reached me a week later, had developed numerous conidia which germinated readily both in water and in nutrient agar cultures. It would appear, therefore, that although evidences of the formation of acervuli may be noted early in June, mature conidia are not present in quantity before August or September.

Sections through a mature acervulus (*fig. 8*) show a subepidermal stroma from which arise comparatively long closely compacted basidia, on which the elliptical curved conidia are borne. As growth proceeds the overlying epidermis is ruptured and the

mature conidia are set free. A true pycnidium is not developed. When first exposed the conidial mass is a delicate creamy tint, but with age its outer surface becomes dark colored or even black. The conidia (*fig. 9*) are continuous, hyaline or with a greenish tinge, elliptical, curved, coarsely granular, and measure $5–7 \times 16–28\mu$. They average about $6 \times 24\mu$.

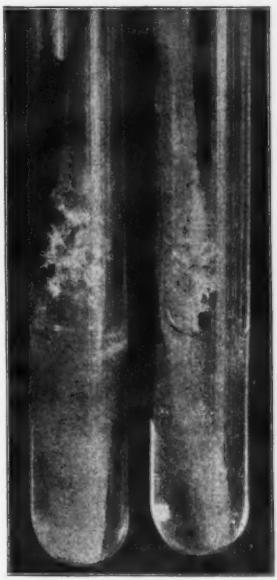

FIG. 4.

Late in July dilution cultures were made in neutral and in acid potato-agar from material that had been collected the last of June. In these cultures not a single colony developed. October 4 similar cultures were made from material which was collected about the middle of July. In this but two conidia could be found that had germinated. In fact so few conidia had developed that it was difficult to obtain enough for satisfactory cultures without obtaining an extensive variety of contaminating growths. To obviate this difficulty, on October 6 conidia from a single acervulus were carefully removed with a flamed scalpel, teased out in a drop of sterilized water, and transferred with a sterilized camel-hair brush to marked places on plates of acid potato-agar. These plates were examined daily, and although numerous spores were seen none were observed to germinate until October 10, when two which had made a feeble growth were transferred to tubes of sterilized bean stems. At the time the general failure of the spores to germinate was thought to be due to their loss of vitality through having been kept too long in the laboratory; but it now appears to have been because the conidia used were not mature, since spores from material collected October 4 have continued to germinate readily up to the middle of November.

In cell and in Petri dish cultures in potato-agar the conidia germinate readily in about twelve hours at a temperature of 22° C. At 29° the germination is retarded indefinitely, although spores in cell-cultures

which had been kept at this temperature in the thermostat for 24 and 48 hours germinated as usual when removed to the lower temperature. A germ-tube is developed at one end of the conidium (*fig. 10*) and the protoplasm begins to flow into it. Soon another tube pushes out, usually from the opposite end of the spore, and this is followed by others until from two to five tubes have been produced. In nearly all

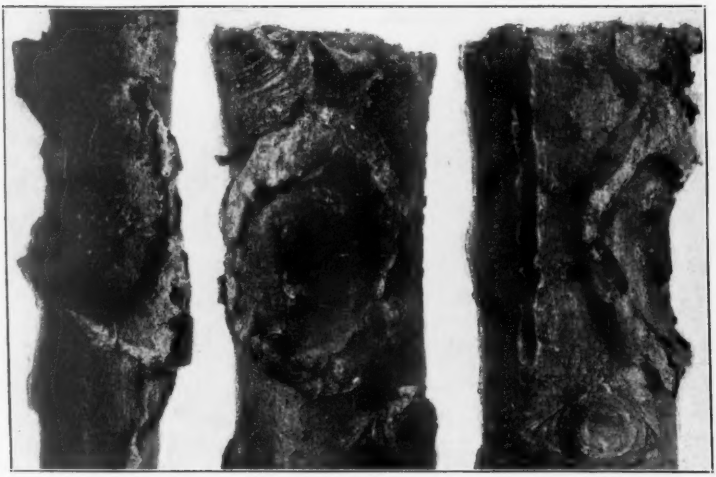

FIG. 5. FIG. 6. FIG. 7.

instances there is a slight bulbous enlargement at the origin of each tube, much as is *Gloesporium nervisequum*, but less marked.[1]

Growth is comparatively slow, and at 24 hours from the time of sowing the germ-tubes are rarely more than twice the length of the spore. Even at this early stage, however, the production of secondary conidia has begun (*figs. 11, 12*). These are generally produced acrogenously from short lateral outgrowths of the germ-tubes, or of the conidium much as described for *Gloesporium fructigenum*,[2] and for *Colletotrichum gossypii*.[3] The branches are, however, much shorter, and

[1] STONEMAN, BERTHA: A comparative study of the development of some anthracnoses. BOT. GAZ. **26**: 69. *pl. 12*. 1898.

[2] *Ibid.*

[3] ATKINSON, G. F.: Anthracnose of cotton. Jour. Myc. **6**: 173–178. 1891.

numerous instances have been observed in which no such outgrowths could be seen, the secondary conidia having every appearance of being given off directly from the germ tube or even from the conidium itself. They are at first hyaline, later with a greenish tinge, granular, elliptical, rarely slightly curved, and always, so far as observed, decidedly smaller than the original conidium, although varying greatly with the character of the food supply. The most abundant production of these secondary conidia is in the immediate vicinity of the conidium, so that there is a tendency to produce an acervulus.

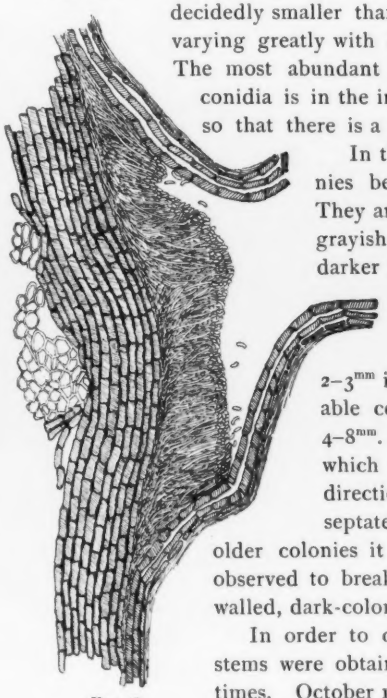

FIG. 8.

In three or four days the stellate colonies become visible to the unaided eye. They are circular in shape, with a slight grayish tinge, elevated and somewhat darker in the center, where the production of secondary conidia is most abundant. In crowded cultures they rarely become more than 2–3^{mm} in diameter, but under more favorable conditions may attain a diameter of 4–8^{mm}. In its earlier stages the mycelium, which radiates quite uniformly in all directions from the center, is sparingly septate and without vacuoles. In the older colonies it becomes vacuolated, and has been observed to break up into chains of irregular thick-walled, dark-colored cells.

In order to check the results, cultures on bean stems were obtained in various ways and at different times. October 10 two colonies, which were supposed to have developed from the Gloesporium spores, were transferred from Petri dish cultures to tubes of sterilized acid bean stems. October 12 the conidia from a single acervulus were teased out in sterilized water, and with the tip of a sterilized needle a very few spores were transferred to each of several tubes of bean stems. October 17 six more colonies were transferred from plate cultures to tubes of bean stems, and four days later four more tubes were inoculated by transferring colonies which had been grown in cell cultures. On the 17th a dilution color was made in acid potato-agar. On the 18th, after the

spores had germinated, a number of them were carefully marked, and on the 21st, when the colonies had become visible to the unaided eye, six of them were carefully transferred to tubes of acid bean stems and three to tubes which had not been made acid. October 25 a similar dilution culture was made, in which on the following day a number of colonies were carefully marked. These plates were then allowed to stand until November 14 in order that any foreign growths which might be present should have an opportunity to develop, when eight of the marked colonies which still remained entirely distinct from all other growths were transferred to acid bean stems.

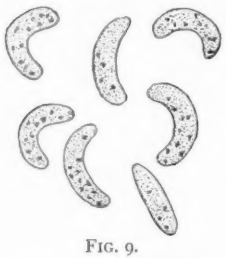

FIG. 9.

The first growth to appear on bean stems is invariably the production of a few scattered, comparatively thick, more or less branched, stromal growths, which arise above the substratum at the point of infection. These shortly become covered with a growth of flocculent white mycelium, and from this center the entire surface of the stem and of the liquid becomes covered with a dense gelatinous looking stroma, which on the surface of the stem is covered with the mycelium (*fig. 4*).

In the course of ten days or two weeks there is usually an abundant production of sori, which are of an olive-green color when seen by transmitted light, but give to the surface of the stroma a glistening black appearance when viewed by reflected light. In the older cultures the stroma has invariably become a deep salmon color, the cause of which has as yet not been determined. We have also observed slight elevations of the stroma which suggested the development of an acervulus, although in no such instances have conidia been observed. In a few instances we have also observed on the surface of the stroma small spherical, olive-green, perithecium-like bodies, covered with a scant mycelial growth, which possibly presage the development of an asciger-ous form. In no instance, however, have asci been found in these bodies.

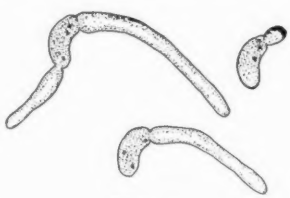

FIG. 10.

To determine whether the fungus studied is the cause of the disease under consideration, on October 30 thirty-six inoculations were

made on sections of apple limbs. Twelve sections, each from 0.75 to 1.50 inches in diameter and 4 to 6 inches long, were selected and divided into groups of four sections each. One of these groups was thoroughly washed in a solution of mercuric chlorid (1 to 1000), after which it was thoroughly rinsed in water. The other two groups were left untreated. The sections in each group were numbered 1, 2, 3, 4, and upon each section three inoculations were made. On sections 1 and 3

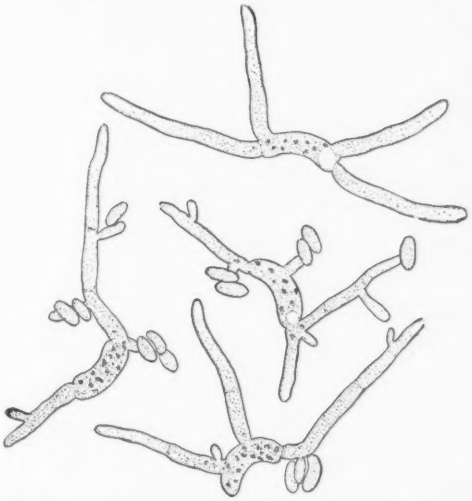

FIG. 11.

in each group the inoculations were made by scraping up the epidermis with a flamed scalpel and applying directly to the exposed cortex and cambium small portions of bean stem culture bearing an abundant mycelial growth and conidia. In inoculating sections 2 and 4 care was taken to select portions on which the bark was uninjured and to make the applications without in the slightest abrading the epidermis. The sections when prepared were placed in fruit jars containing moist sand, which had been thoroughly sterilized by steam heat. In about a week after the inoculations were made slightly discolored areas were observed about several of the points of infection, and by November 20, three weeks from the time they were made, these areas had developed all the characteristics of the disease as seen in nature; being

brown, distinctly depressed and separated from the surrounding healthy portions by a zone of hypertrophied tissues which are marked by numerous ragged fissures in the epidermis, through which the underlying chlorophyll-bearing tissues may be seen (*figs. 5, 6, 7*). The peculiar appearance of this zone attracted the attention of Professor Atkinson, who on examination found it to be due to an œdematous condition of the tissues produced no doubt by the excessive supply of moisture in the jars and by the stimulating effect of the fungus. Por-

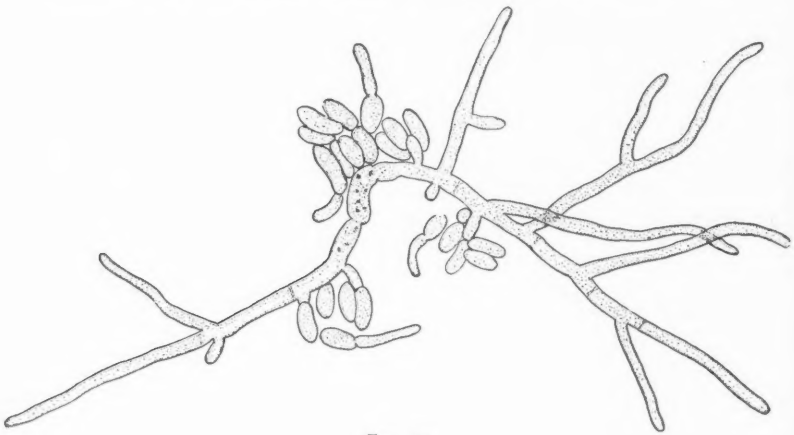

FIG. 12.

tions of these tissues were selected for a more careful histological study, but they were unfortunately lost in an accident and we can only refer for a consideration of œdematous tissues to an article by Professor Atkinson on the œdema of the tomato.[4]

It was hoped that by applying some of the spores to wounded tissues, while care was taken to apply others to uninjured areas of the cuticle, some light might be thrown upon the manner in which the fungus first gains entrance to the cortical tissues; but owing to the fact that no results were obtained from any of the sections treated with mercuric chlorid the test was unsatisfactory.

At the beginning it was realized that such inoculations would not offer absolute proof of the parasitic nature of the fungus, since it is of

[4] ATKINSON, G. F.: Œdema of the tomato. Bull. Cornell Univ. Expt. Sta. 75: 108. *pl. 8.* 1893.

course possible that sections of limbs may offer less resistance to the fungus than they would had they not been removed from the tree. But the fact that these sections were taken from the tree in the fall, and were inoculated immediately before any great change in the tissues could have taken place, together with the fact that the inoculations were followed by such virulent attacks of the disease, seems to offer at least a very strong probability of its parasitic nature.

The fungus, which appears never to have been described, may be characterized as follows:

Glœosporium malicorticis, n. sp.— Parasitic in the cortex of branches of *Pyrus malus*. Affected areas dark brown, limited by ragged irregular fissures, sometimes 5–7.5×15–20^{cm}, occasionally girdling the branch. Acervuli scattered, triangular, rupturing the epidermis, 300–800 μ in diameter. No pycnidia. Conidial mass at first cream-colored, later dark. Conidia borne on upright basidia, which arise from a subepidermal stroma. Conidia continuous, coarsely granular, at first hyaline, later with greenish tinge, elliptical, curved, sometimes geniculate, 5–7×16–28 μ, average 6×24 μ. Those grown in cultures smaller and rarely curved.

To Professor G. F. Atkinson, of Cornell University, I am greatly indebted for advice and assistance.— A. B. CORDLEY, *Oregon Experiment Station*.

NOTE.— Since this article was written, in November 1899, what is probably the same fungus has been described by Professor C. H. Peck in the January number of the *Bulletin of the Torrey Botanical Club*, under the name of *Macrophoma curvispora*. If this supposition proves to be correct the name proposed by me will of course have to be abandoned.—A. B. C.

EXPLANATION OF FIGURES.

FIG. 1. *Glœosporium malicorticis* Cordley; front view of depressed area on apple limb, natural size; photograph taken after the limb had dried.

FIG. 2. Same, side view.

FIG. 3. Front view of old and dead area on a living apple limb, natural size; photograph taken after the limb had dried.

The above three apple limbs were from Oregon, and were photographed by Miss Agnes Vinton Luther in the Botanical Laboratories, Cornell University, during the summer of 1899.

FIG. 4. Fluffy colonies of the pure culture of the fungus in test on bean stems, natural size.

FIGS. 5 and 6. Front view of depressed area as a result of inoculation of pure cultures on sections of living apple limbs at Cornell University.

FIG. 7. Same as *fig. 6*, side view.

Photographs 4–7, by H. Hasselbring, all natural size.

FIG. 8. Section of an acervulus on apple limb showing the basidia and conidia.

FIG. 9. Conidia.

FIG. 10. Conidia germinating.

FIG. 11. Conidia germinating; secondary conidia forming, some of them arising very near the original conidium.

FIG. 12. Germinating conidium with mycelium and new conidia.

NEW CARYOPHYLLACEÆ AND CRUCIFERÆ OF THE SIERRA MADRE, CHIHUAHUA, MEXICO.

THE following plants, except the last species (which was collected some years ago upon the Lumholtz Archæological Expedition), belong to an extensive suite (rich in novelties), which is soon to be distributed by Professor E. O. Wooton, of the Agricultural College at Mesilla Park, New Mexico. The collection was made by Messrs. C. H. T. Townsend and C. M. Barber upon a rather arduous journey to a region as yet but little known.

Cerastium sordidum. — Densely glandular-tomentose and sordid, 2.2^{dm} high: stems thickish, prostrate or nearly so, producing large and slightly fleshy leaf-buds in alternate axils; the foliar leaves, borne chiefly near the ends of these prostrate shoots, oblanceolately acute, 1-nerved, 4^{cm} long, $1–1.4^{cm}$ broad, finely and densely tomentose upon both surfaces, persistent and at length glabrate, white and scarious or marcescent: flowering branches erect, subsimple, arising from the thickish buds above mentioned, bearing 2 to 4 pairs of oblong or linear rather small acute leaves below the middle, naked above, terminating in a few-flowered more or less elongated uniparous or irregular cyme: pedicels $1–1.5^{cm}$ long: sepals ovate, herbaceous, sordid-tomentose, $5–6^{mm}$ long, only the acute apex scarious: petals white, $7–8^{mm}$ long, obovate-oblong, somewhat narrowed below the shortly 2-cleft and more or less crisped summit: stamens 5: capsule straight, erect, 1^{cm} long; the teeth as in § ORTHODON. — Collected by C. H. T. Townsend and C. M. Barber on the Sierra Madre, 8^{km} southeast of Colonia Garcia, Chihuahua, altitude 2310^{m}, 30 May, 1899, no. 40. Type in herb. Gray.

Drymaria Townsendii. — Delicate glabrous annual: stems filiform, $4–10^{cm}$ long, leafy: leaves slightly fleshy, orbicular, 5-nerved, rounded

at the summit, subcordate at the subsessile base, 4–6^{mm} in diameter, about half as long as the internodes, entire; scarious stipules linear-filiform: capillary pedicels spreading, 3–4^{mm} long, borne in the upper axils or in short lateral or terminal one-sided bracteate cymes: sepals elliptical, herbaceous except at the white margin, 2^{mm} long: petals very narrow, appearing like sterile filaments: fertile stamens 5: stigmas essentially sessile upon the ovoid ovary; seeds pale brown, 0.5^{mm} in diameter, muriculate and crested. — Collected by C. H. T. Townsend and C. M. Barber, on the Sierra Madre, 8^{km} southeast of Colonia Garcia, Chihuahua, 5 August, 1899, no. 231. Type in herb. Gray.

Sisymbrium Wootonii. — Suberect glabrous herb, 5–6^{dm} high, branched above; stem glaucous, terete, leafy: leaves obovate-oblong, 5–10^{cm} in length, 1.8–3^{cm} in breadth, obtusish, cuspidate, entire, thin, somewhat glaucous at least on the lower surface, sessile and auriculate-clasping: pedunculate racemes about 6, erect; pedicels 1–2^{cm} long, glabrous, spreading, scarcely thickened at the summit: sepals thin, white, broadly oblong, rounded at the apex, 4–5^{mm} long, considerably exceeded by the obovate-cuneate rather broad white petals: young pods 1.4^{cm} long, narrowly linear, erect upon spreading pedicels; style 1.5^{mm} long; the stigma distinctly 2-lobed, the lobes over the placentæ. — Collected by C. H. T. Townsend and C. M. Barber on the Sierra Madre, 16 ^{km} southeast of Colonia Garcia, Chihuahua, 27 July, 1899, no. 176. Type in herb. Gray.

Sisymbrium microtites. — Erect, probably biennial, 4^{dm} high, simple below, glabrous throughout: radical leaves numerous, pinnately parted nearly or quite to the rhachis; the segments about 9, oblong or elliptical, about 8^{mm} long, often with one or more rather salient teeth; cauline leaves 4^{cm} long, irregularly bipinnatifid, the terminal segments linear-oblong, exceeding the lateral; petioles provided with small round clasping auricles at the base: racemes elongated; pedicels spreading, filiform, 1^{cm} in length, scarcely thickened at the summit: flowers rather small: sepals ovate-oblong, obtuse, pale-yellow, 1.7^{mm} long: petals sulphur-yellow, fading white, 2–3^{mm} long: pods erect or curved-ascending, 1.4–1.8^{cm} long, 2^{mm} in diameter, tipped with a short slender style bearing a minute nearly circular stigma; seeds in two rows. — Collected by C. H. T. Townsend and C. M. Barber on the Sierra Madre, 8^{km} southeast of Colonia Garcia, Chihuahua, 2 June, 1899, no. 43. Type in herb. Gray. Readily recognized by its minute orbicular ear-like appendages at the slightly broadened base of the petiole.

Sisymbrium umbrosum. — Erect branched perennial 6^{dm} high; stem pale purple, terete, covered with simple spreading soft white hairs below, nearly or quite glabrous above; slender curved-ascending branches simple: radical leaves several (including the petiole), $1.3–1.5^{cm}$ long; the petiole and midrib densely covered with simple spreading white hairs; the blade lyrate-pinnatifid, appressed-villous on both surfaces, $3.5–4^{cm}$ broad at the widest part; segments rounded and crenately toothed or lobed; cauline leaves much smaller, deeply and rather evenly pinnatifid, short-petioled, exauriculate, the segments 5–9, oblong, acute or acuminate, the sinuses rounded, relatively broad: peduncles $3–10^{cm}$ long; racemes erect, $1.5–3^{dm}$ long; pedicels widely spreading or ascending, sparingly pilose or glabrate, slightly thickened at the summit: sepals ovate-oblong, obtuse, 3^{mm} in length, sometimes villous dorsally: petals white, rather narrow, 6^{mm} long: pods very narrow, linear, about 4^{cm} long, loosely spreading, often curved outward, glabrous, 0.7^{mm} broad, scarcely beaked; the stigma obscurely 2-lobed; the lobes over the placentæ; seeds apparently in 1 row.—Collected by C. V. Hartman in shady places among rocks, Puerto de San Diego, Chihuahua, altitude 2000^{m}, 12 April, 1891, no. 629. Type in herb. Gray. Distributed as *Thelypodium auriculatum*, of which it has somewhat the habit; from this, however, it differs markedly in pubescence and exauriculate leaves. The orientation of the stigma places this species in Sisymbrium rather than Thelypodium.—B. L. ROBINSON, *Gray Herbarium*.

CURRENT LITERATURE.

BOOK REVIEWS.

The Flora of Montana.[1]

NOT since Dr. Coulter's *Manual of the Flora of the Rocky Mountains* was issued has so important a contribution to the botany of this region appeared as Dr. Rydberg's work which now lies before us. The workers in this vast empire, known as the Rocky mountains, learned with pleasure, some months since, that this author was engaged upon a *Flora of Montana*, and its appearance was awaited with some impatience. The magnitude of the task was probably only half appreciated even by those who are actively engaged in the study of the plants of this same general region. Though the title-page denominates it a *catalogue* of the flora, it is far more than that, and is likewise more than an annotated catalogue. Each species is treated almost exhaustively: citations of publication, the more important synonymy, notes upon habitat and distribution are given, and following this an enumeration of the specimens examined. In the case of new species, specimens from adjacent states are also cited, in so far as they were known to the author.

The introduction is interesting in showing the circumstances which led to the inception of the enterprise, with some history of the exploring expeditions which secured, in part, the collections upon which the *Flora* is based. Nearly all the collections that have been made from the time of Lewis and Clark to the present seem to have been available for study, and it is really remarkable how many expeditions have touched to a greater or less extent upon Montana soil.

In the development of the botany of western America it is noticeable that the early explorations were, in large part, in the far west or northwest; that even the arctic portions of British America were known long before the interior west of the United States. The names now so familiar to us as collectors and explorers, Drummond, Douglas, etc., are embalmed in the literature which has been the basis of west American botany. In the Rocky mountain region of the United States the southern half was developed earlier than the northern, as witness the work of Fendler, of the Mexican Boundary Survey, of the Wheeler Expedition, etc. In the northern half, we have the Pacific Railroad Surveys, King's Expedition, Parry's and Coulter's Reports, etc., but even these dealt largely with the plants of the Pacific slope

[1] RYDBERG, PER AXEL: Catalogue of the Flora of Montana and Yellowstone National Park. Memoirs of the New York Botanical Garden. Vol. I. 8vo. pp. xi + 492.

rather than those of the eastern slopes of the Rocky mountain range. Nuttall, it is true, must have collected over a very large area of this interior west, but what is one man's work in such a vast region, even though he be a Nuttall? Keen in observation, discriminating in description, Nuttall stands without a peer as regards the field in question. For sixty years following his time some of the regions that he visited have not been entered by other botanists. On account of the inadequate specimens that he made, and their inaccessibility to the majority of workers, many of his species were for years rather discredited, or at least misunderstood. With the renewed interest that has sprung up during the last decade, Nuttallian species are again at par. Furthermore, new ones are being described by the score every year. From a long period of conservatism, during which the plants of the interior west were often disposed of as mere forms of species of widely different geographical range, we have now come to look upon this flora as quite as sharply defined as that of any other area of equal size. In the work before us we have an excellent example of this tendency.

The remarkable number of 1976 species and varieties are reported in Dr. Rydberg's *Flora*, though only the Spermatophytes and Pteridophytes are included. Of these the author indicates 776 as not found in Coulter's *Manual*, including 163 which are described as new. A few species have been admitted simply on report, but the author aimed to admit only those which rest upon good authority. In spite of this excellent showing as to numbers, the author assures us that large sections of the state are still almost a *terra incognita*. Should these portions of the state yield in the same ratio, and the other Rocky mountain states prove equally prolific, the future Manual of the Rocky mountains will be a work of no mean magnitude.

Altogether the work is so admirably done, and contains so much of value to those who are interested in the taxonomy of western seed-plants, that one might be justified in wholly overlooking any inaccuracies, and in avoiding all discussion of those conclusions which rest, in a measure at least, upon individual judgment. But it may not be out of place to call attention to some matters that the author desired otherwise as much as anyone, and to some of the points raised which may be clarified by discussion.

The large number of species reported would have been materially reduced had the work been done by one more conservative. What constitutes a specific difference is still one of the unanswered questions, and is likely to remain so for sometime, but it is easily discoverable that to the describer with the plant in hand the differences appear more fundamental than they do to one who has to perceive them solely through the description. Dr. Rydberg's treatment illustrates this. In Dodecatheon he lists ten species, describing five as new, some of which seem to the reviewer to be based upon inadequate differences and insufficient material. For instance, of *D. pulchrum* it is stated "it agrees with the description of *D. conjugens* Greene except

that the petioles of the leaves are obsolete," and then he founds the species on Mr. Tweedy's no. 432, in part, the other part being cited under *D. cylindrocarpum*, another new species which is also said to be nearly allied to *D. conjugens*. The familiar *Arnica alpina* Olin (or more properly *A. fulgens* Pursh) has come in for its share of segregation. Three or four species are recognized, but the writer is unable to discriminate between them, and somehow has the feeling that here we have had a splitting of hairs. Likewise Phyllodoce (Bryanthus) has had critical attention, four species being recognized, though it is suggested that two of them may be hybrids. Of these four species two were collected by the writer last summer (*P. empetriformis* and *P. intermedia*), both growing in the same little patch in an alpine gulch, and no difference was detected except that of color. Other genera might be mentioned, but one need not cite further examples.

Somewhat in contrast with this is the occasional accrediting to Montana of species that are supposed to belong to quite a different geographical range. *Erigeron speciosus*, *Claytonia Virginica*, and *Phlox Douglasii* may serve as examples. The following names occur in the first seventeen pages of the text, though no specimens are cited: *Dryopteris Filix-Mas*, *Pinus scopulorum*, *Abies amabilis*, *Juniperus occidentalis*, *Potamogeton natans*, and *P. Robbinsii*. It is hardly necessary to state in this connection that the work does not seem to be even; some genera have received the most painstaking treatment, while others have been handled in a less critical manner. This, however, could scarcely be otherwise in a work of such magnitude.

It may be interesting to note that there are discoid forms in *Erigeron trifidus* as well as in *E. multifidus*, and that if these are to be recognized as a variety in one we must do so in the other. It would not be surprising to find that *E. compositus* Pursh also has its discoid forms.

Much obscurity in the past as to the limits and identity of species has been caused by inadequate descriptions. So here the descriptions, in some instances, seem likely to give rise to similar confusion, not always because of their brevity, but rather because of the omission of essential characters. In *Carduus canovirens* very characteristic pubescence of two kinds is passed over as "more or less woolly." In *Artemisia tenuis* we have no mention of the flowers as to number, form, size, or kind, nor of the akenes, though to this species is appended a variety, "growing with the type," to which less than two lines is devoted. However, authors will of necessity differ as to what are essentials.

Washingtonia divaricata (Nutt.) Britt. and *Phlox andicola* (Nutt.) Britt. are examples of a practice in which the author is not in accord with most other writers. Nuttall did not describe these species, and though he had used the mere names he should not be cited as if he were the author: Dr. Britton in the *Illustrated Flora* very properly did not do so.

A matter of punctuation: In harmony with the general practice at present, Dr. Rydberg writes *Mimulus Lewis* Pursh, Fl. Am. Sept., but writes *Monniera rotundifolia* Michx. Fl. Bor. Am. The query in my mind is, if we use a comma to separate the author's name from the name of the publication in one case, why not in the other? The period is a part of the abbreviated name and does not set it off from the name of the publication. Why not write *M. rotundifolia* Michx., Fl. Bor. Am.?

In most instances the approximate altitudinal range for the species is given, a practice to be commended, though such statements must always be allowed some additional variation, since so much depends upon the exposure and general conformation of the country. Especially is this true where but few collections are at hand upon which to base the statement. On this account it is sometimes a little amusing to note that a definite range is sometimes given when but a single collection was known, as for instance in *Atriplex hastata*, *Grayia spinosa*, *Abronia fragrans*, *Washingtonia longistylis*, etc.

As mere slips, typographical or otherwise, may be noted the following: On p. 130 Shoshone lake is accredited to Montana; on p. 184 the notes speak of *Sophia canescens*, though I think the *Sisymbrium canescens* Nutt. has never been transferred to that genus; on p. 417 *Balsamorrhiza sagittata* Nutt. should be *B. sagittata* (Pursh) Nutt.; on p. 377 the *not Pursh* following *Valeriana pauciflora* Hook. should read *not Michx.;* on p. 386 the *Solidago multiradiata* listed is more probably *S. multiradiata scopulorum*. It may be noted, too, that in some instances the notes upon a species are not in accord with the name. While the *Flora* was going through the press it became necessary to change from the original name selected, and the notes were not altered to correspond. In one or two instances A. Nelson is credited with a species that belongs to E. Nelson, *e. g.*, *Pellæa occidentalis*, p. 466.

Of course the author uses the Engler and Prantl arrangement which can scarcely fail of universal approval. The application of the Rochester rules has resulted in the displacement of some of the familiar names, and even to one who thoroughly believes in the principle of priority it is a source of regret that it should necessitate so many changes.

All errors aside, the volume before us, with its nearly five hundred octavo pages, will prove invaluable to the working botanist, and will also prove of interest and service to the amateur, though it is not put out as a manual of the territory covered. It reflects great credit upon the author, and is an honor to the New York Botanical Garden from which it is issued as Volume I of its *Memoirs*. The excellent paper, luxurious type, and broad margins, make it a pleasure to the eye.—AVEN NELSON.

The Cell.

THE first edition of Professor Wilson's work[2] on the cell, which appeared in 1896, met a hearty welcome from biologists everywhere; it was reprinted the next year with the addition of an appendix which summarized the recent literature, and was again reprinted in 1898 with a similar appendix, but the literature of the subject had increased so much and the aspects of important problems were changing so rapidly that something more than an appendix was needed to bring the book up to date. Accordingly the entire work has been thoroughly revised, and over one hundred pages and fifty figures have been added. The problems of the centrosome, cell division, and fertilization, have been materially changed, some of the sections having been entirely rewritten. Recent experimental work in these subjects and in regeneration have received special attention. Changes and additions, however, are not confined to these subjects, but are found upon almost every page.

The treatment, as in the previous edition, is historical, and the careful citation of specific authority which enables the reader to weigh for himself the statements of the text makes the book indispensable to cytologists, whether they be zoologists or botanists.

The book, though still confessedly weak in the field of botanical cytology, shows a decided improvement over the previous edition, especially in the subjects of cell division, spermatogenesis, and fertilization. It is helpful to the botanist to get a view of his own problems from a zoological standpoint.

It is of special interest to botanists to note that the author regards the blepharoplasts of Gingko, Cycas, Zamia, Marsilea, etc., as genuine centrosomes, although he believes that Webber and Ikeno have produced apparently strong evidence that they arise separately and *de novo* in the cytoplasm.

He hesitates to accept Shaw's statement that in Marsilea the "blepharoplastoids" have no relation to the blepharoplasts which appear later; a decision is also withheld in regard to Webber's conclusion that in Zamia the blepharoplasts have a separate and independent origin. In regard to vegetative mitoses of the higher plants the statement is made that we should still hold open the possibility that centrosomes may occur, their apparent absence being possibly due to lack of staining capacity or similar conditions rendering their demonstration difficult.

"In the female the two maturation divisions give rise to the four primary cells of the embryo sac: and these two divisions undoubtedly correspond to the two maturation divisions in animals. In the female only one of the resulting cells gives rise to the egg, the other three corresponding to the

[2] WILSON, E. B.: The cell in development and inheritance. 2d edition, revised and enlarged. 8vo., pp. xxi + 483, *figs. 194*. New York: Macmillan Company. 1900. $3.50.

polar bodies of the animal egg, though they here continue to divide and give rise to rudimentary prothallium."

Morphologists of today can hardly accept the statement that the "pollen tube represents a rudimentary male prothallium or sexual generation."

The paragraph on fertilization in plants has been considerably improved, notably by the account of double fertilization in angiosperms.

Considerable space is devoted to the reduction of the chromosome in plants, but no decision is reached as to whether there is a reducing division such as has been described by vom Rath and others.—C. J. CHAMBERLAIN.

MINOR NOTICES.

A SECOND EDITION of Wiesner's *Die Rohstoffe des Pflanzenreiches* has begun to appear from the press of Wilhelm Engelmann.[3] Three parts, each containing 160 pages, have already been published, and the remaining two parts of the first volume are promised before the close of the present year. Another volume of the same size will be needed to complete the work, and probably its publication will be well advanced within the year.

As compared with the first edition, issued in 1873, the present is completely rewritten and extended to about double its former size. In the present parts Professor Wiesner writes the introduction (47 pp.) and the sections on gums (82 pp.), and resins (226 pp.); Professor K. Mikosch writes on the caoutchouc group (43 pp.), the catechu group (14 pp.), and the fats (incomplete); Professor A. E. Vogl on opium (14 pp.) and aloes (10 pp.); and Professor H. Molisch on indigo (24 pp.).

This collaboration (the complete list of collaborators, as announced, includes eleven names) puts the different subjects into the hands of specialists and insures prompter completion of the work.

In each section, varied to suit the special case, the general plan of treatment includes an account of the plants yielding the substance and their distribution, the mode of obtaining it, its commercial characteristics, its physical, chemical, and microscopical qualities, and its uses. Both botanical and technical users, therefore, will find this work a mine of information regarding plant products.—C. R. B.

THE ELEVENTH EDITION of Prantl's *Lehrbuch der Botanik*[4] has been issued by Engelmann. The revisions of this popular text-book have been under the charge of Dr. Pax, of Breslau, since the death of the author.

[3] WIESNER, JULIUS: Die Rohstoffe des Pflanzenreiches. Versuch einer technischen Rohstofflehre des Pflanzenreiches. Zweite gänzlich umgearbeitete und erweiterte Auflage. Leipzig: Wilhelm Engelmann. 1900. Pro lief. *M* 5.

[4] PAX, FERDINAND: Prantl's Lehrbuch der Botanik. Elfte verbesserte und vermehrte Auflage. 8vo, pp. viii + 455, *figs. 414*. Leipzig: Wilhelm Engelmann. 1900. *M* 4.60; geb. 6.10.

Without changing the plan of the book its statements have been changed to conform to recent discoveries. But a more thorough change, especially to strengthen the physiological section (of only 50 pp.), seems desirable. The main emphasis is laid on the third part, the taxonomic synopsis of the plant kingdom, nearly half the book being devoted to descriptions of families and orders of phanerogams. There must be a demand for this sort of thing in Germany, especially in the schools of pharmacy, else there would not be so many text books in which it is prominent. But it is hard to see of what possible didactic value it can be, and the space would be better used if devoted to a thorough discussion of the fundamentals of morphology and classification.—C. R. B.

THE FIRST FASCICLE of the list of the genera of seed plants, according to the system of Engler, has appeared.[5] The large page is divided into two columns, and all of the divisions down to the genera are given. The genera are numbered in double sequence, the first number indicating the place in the whole series of genera, the second number indicating the place in the family. In these first signatures 1268 genera are listed, beginning with *Cycas* and closing with *Marica* (Iridaceæ). Under each genus there are given the important citations, the synonymy, the approximate range and number of species. In the case of larger genera the section names and their synonymy are given. This work will not only be indispensable in herbaria, but will be a mine of handy information to the general student of morphology and taxonomy.—J. M. C.

A NEW EDITION of the Bonn text book,[6] the fourth, has been issued by Fischer, with the purpose of keeping this incomparable work abreast of the science of botany. The authors have incorporated from the newer literature everything which appears to them to be of scientific or didactic value. Certain sections of the part on external morphology have been extended, some new illustrations have been added and some old ones replaced by better. The general plan of the book is not altered. It has become so well known that there is no need to speak of its merits or defects. We hope that the translator of the English edition will take advantage of the new German edition to bring the English one also up to date and correct some slips of translation.—C. R. B.

[5] DALLA TORRE, C. G. DE, and HARMS, H.: Genera Siphonogamarum ad systema Englerianum conscripta. Fasciculus primus (signatura 1–10). Small 4to, pp. 80. Leipzig: Wilhelm Engelmann. 1900. *M* 4.

[6] STRASBURGER, NOLL, SCHENCK, and SCHIMPER: Lehrbuch der Botanik für Hochschulen. Vierte verbesserte Auflage. 8vo, pp. viii + 588, *figs.* 667. Jena: Gustav Fischer. 1900. *M* 7.50.

NOTES FOR STUDENTS.

IN SEARCH of an explanation for mycorhiza Dr. E. Stahl has made a comparative study of broader scope than any involved in the previous researches upon the subject.[7] The interesting conclusion of extended observations upon the distribution of mycorhiza is that, hydrophytes aside, the large majority of vascular plants possess it. Its occurrence, in the words of the author, "has an intimate relation with increased difficulties of nutrition."

That photosynthesis is so intimately conditioned by transpiration as to be approximately in direct proportion to it is a fundamental premise of Stahl's conception. Further, it is assumed as demonstrated that the host, in the presence of mycorhiza, possesses a nutritive advantage. Now if it be found that mycorhiza is coincident with low transpiration, may not the nutritive advantage of the former provide a certain compensation for the weakness of the latter? Indeed the author seeks to refer the inception of mycorhiza to comparative weakness of absorption as an original cause. For, he argues, a root system unable to supply the green parts with a transpiration stream carrying nutrient salts commensurate with the demand would at once induce a need for equivalence of organic substances which it is the function of the mycorhiza habit to supply. Holding with Frank that the humus soil of forests is in large part "a living mass of innumerable fungal hyphæ," the discussion of competition for nutrient salts upon forest floors leads to the conclusion that, unless possessed of root-systems of exceptional absorbent efficiency, the vascular green plant is placed at decided disadvantage; this notwithstanding the great and apparently available store of nutritive material, and on account of the ubiquity and chemotropic advantage of the rival fungal hyphæ. The obligate mycorhiza plants with low transpiration cannot, it is argued, independently compete for nutrient salts with vascular plants of high transpiration or with the fungi, but they escape the stress of that competition by making tributary to themselves certain fungi from which they supplement the supply of elaborated organic compounds. That holosaprophytism involves no more than increased reliance upon the fungal tributaries and corresponding loss of even potential photosynthesis is obvious. Stahl attributes the inception of the parasitic and carnivorous habits to the same handicap in competition for the nutrient salts. There should be noted herein a certain parallelism of argument with the claim of Frank for definition of endotrophic mycorhiza as "fungus-traps," although Stahl does not agree with Frank in holding to a different physiological significance between the ectotropic and endotropic forms.

It is quite unlikely that the author will escape criticism for the breadth of certain of his generalizations or for his use of certain facts as positive

[7] STAHL, E.: Der Sinn der Mycorhizenbildung. Jahrb. f. wiss. Bot. **34**: 539–668. 1900.

criteria when an interpretation totally at variance from that upon which his conclusions depend is at least admissible. Thus at the very outset he devotes a number of pages to the discussion of "criteria for the relative water-demand of plants." He seeks a ready means of determining in extended observations whether or not mycorhiza when present is associated with reduced transpiration, as his hypothesis demands. The presence of starch rather than sugar in the leaves is selected as the foremost characteristic for his purposes indicative of greater transpiratory activity. "For," he writes, "the advantage of starch formation lies very largely in the promotion thereby of transpiration, since reduced concentration stimulates the evaporation rate; and, inversely, an increase of the dissolved substances, glucose, for example, must have a retarding effect." But it is a fair question whether starch may not appear only after a maximum concentration has been attained, and hence its absence regarded as favorable rather than opposed to transpiration.

Certain experiments upon *Sinapis alba*, *Linum usitatissimum*, and *Triticum vulgare*, forms free of any trace of mycorhiza, are of interest in affording striking contrast with Frank's experiments upon beech and pine seedlings. In the latter case, as is well known, the development in a sterilized soil of seedlings normally possessed of mycorhiza was strikingly deficient in contrast with individual plants in unaltered humus soil. But, if the contention of Stahl is sustained, autotrophic forms should flourish in especial degree in soil where they are freed of the rivalry of fungi, which unlike their more specialized mycotrophic kin, they are unable to make tributary; *i. e.*, exactly the reverse of the results with mycotrophic forms. And such is found to be the case in striking degree. Incidentally, however, an excursion is made to demonstrate the retarding effect of abundance of nutrient salts upon root growth. For, though the shoot is feeble, the root system, as is reasonable to expect, becomes more elongated in the autotrophic forms grown in competition with the fungi.

That part of the paper which deals with "the absorption of nutrient salts and the ash-content of mycotrophic as compared with autotrophic plants" is none the less important in that it seems to belong as a closing chapter to such special studies of this subject as those of MacDougal and Groom rather than to a contribution so broadly comparative in character as this one. The introductory argument that the ash content of mycotrophic plants should have certain specific differences from that of autotrophic forms is more safely founded upon the previous and detailed study of others, than upon a general association of mycorhiza with forms limited in their possibilities of independent food-elaboration, however broad and striking that association may be. Suffice it for the argument that his examples show a certain parallelism to exist between a greater ash-content and autotrophy on the one hand, and less ash-content and mycotrophy on the other. This tends to

confirm the idea that mycotrophic plants receive from the fungi certain necessary mineral substances already in the form of organized compounds, for thereby they would be relieved to that extent of the necessity, which devolves upon all wholly independent forms, for receiving into the plant body a certain mineral surplus, of which calcium, received as the sulfate, nitrate, or phosphate, is a conspicuous example.

Whatever the disappointment may be that by this contribution, the question of distribution aside, we are no nearer than before to positive knowledge of the nature of this remarkable symbiosis, it is the presentation of an admirable hypothesis of the general function and distribution of mycorhiza, supported by a wealth of evidence which subsequent studies are far from likely to controvert. To the practical physiological ecologist the lists and detailed discussion of mycorhiza distribution will be found invaluable.

New data as to the mycorhizas of holosaprophytes and the structural degeneracy attendant upon this symbiosis are presented by MacDougal and Lloyd.[8] Species of Pterospora, Sarcodes, Hypopitys, and Monotropa were examined. Special emphasis is laid upon the profound morphological alterations of the host which ensue from such complete symbiosis as that which exists between the Monotropaceæ and the ectotropic fungi of its roots. In this family the shoots are to be regarded as physiologically insignificant in the economy of the plant, being purely reproductive in purpose and comparatively ineffective in that function. The roots, which reproduce the plant, serve as organs of storage, are the habitat of the fungus, the absorbing member of the symbiosis, and are the seat of the chief activities of the plant. Pterospora shows an interesting exception to the general tendency of shoot reduction in its development of a comparatively large branched aerial portion which is supplied with stomata.—J. G. COULTER.

ITEMS OF TAXONOMIC interest are as follows: In *Proc. Biol. Soc. Washington* (13 : 129–132. 1900) C. L. POLLARD has published eight new species. belonging to Lupinus, Viola (2), Gentiana (3), Chrysopsis, and Solidago.—The species and hybrids of *Mentha*, a paper by ERNEST MALINVAUD, has been translated into English and published in *Journ. Bot.* 38 : 171–174. 1900. —A list of the angiosperms of Delagoa Bay, Africa, has just been published by HANS SCHINZ (Zürich) and Henri Junod (Delagoa Bay) in *Mém. de l'Herb. Boiss.* (no. 10. March 30, 1900.) No. 11 of the same series (issued April 30) is devoted to a continuation of *Species Hepaticarum*, by FRANZ STEPHANI, the genera *Hymenophytum* (4 spp.), *Pallavicinius* (22 spp., 5 new), *Symphyogyna* (39 spp., 14 new), and *Monoclea* (2 spp.) being included. No. 12 of the same series (issued April 30) contains an account (with 4 plates) of the European species of *Utricularia*, by FR. MEISTER, together with a

[8] MACDOUGAL, D. T., and LLOYD, E. F.: The roots and mycorhizas of some of the Monotropaceæ: Bull. N. Y. Bot. Garden 1: 419–428. 1900.

discussion of their anatomical and ecological features. No. 14 of the same series (issued May 30) contains an account (with 1 plate) of the Japanese Mutisiaceæ from the collection of Faurie, by A. FRANCHET. No. 15 of the series (issued May 30) contains an account of certain new or little known Chytridineæ, by E. DE WILDEMAN.— Notes on some type specimens of Myxomycetes in the New York State Museum is a useful paper by W. C. STURGIS, published in *Trans. Conn. Acad. Arts and Sci.* **10**: 463–490, *pls. 60, 61.* 1900.— F. E. LLOYD and L. M. UNDERWOOD (*Bull. Torr. Bot. Club.* **27**: 147–168. *pls. 2–4.* 1900) have published a review of the North American species of *Lycopodium*, recognizing 29 species, two of which are described as new.— P. A. RYDBERG (*ibid.* 169–189. *pls. 5, 6*) has begun a series of papers entitled "Studies on the Rocky Mountain Flora," the first one being devoted to the *lobatus, aureus, subnudus*, and *tomentosus* groups of *Senecio*, in which assemblage of forms he recognizes 30 species, 18 of which are described as new.—W. R. MAXON (*ibid.* 197–199) has described a new *Asplenium* from southern and Lower California.— S. C. STUNTZ (*ibid.* 202–211) has published a revision of the N. Am. species of the genus *Eleutera* (Neckera), recognizing 6 species, all with new names.—G. N. BEST (*ibid.* 221–236. *pls. 7, 8*) has published a revision of the N. Am. species of *Pseudoleskea*, recognizing 7 species, two of which are new, and 4 varieties, all of which are new.— E. P. BICKNELL (*ibid.* 237–246) has reached his seventh paper on *Sisyrinchium*, which deals with the species of British America. He recognizes 8 species, one of which is described as new, and there is no reason to question his statement that "there is no doubt that this number may be increased."—W. W. ROWLEE (*ibid.* 247–257. *pl. 9*) has published an account of the *longifolia* group of willows as displayed in North America. He recognizes 12 species, three of which are described as new, and 3 varieties, all of which are new.—AVEN NELSON (*ibid.* 258–274), in continuing his account of new plants from Wyoming, has described 23 new species and varieties.—J. K. SMALL (*ibid.* 275–281), in continuing his notes and descriptions of N. Am. plants, has described 11 new species.— FLORA W. PATTERSON (*ibid.* 282–286) has described 17 new species of fungi.—GEO. V. NASH (*Bull. N. Y. Bot. Garden*, **1**: 429–437. 1900) has described 11 new grasses from the southern states, and a new *Trisetum* from Michigan.—J. K. SMALL (*ibid.* 437–447) has published a revision of the genus *Bumelia* in North America, recognizing 13 species, five of which are described as new.— N. L. BRITTON (*ibid.* 447–449) has described 7 new species of *Crataegus*.—MRS. KATHARINE BRANDEGEE has published a second paper in the series on Cacteæ (*Zoe* **5**: 1–9. 1900), the first having appeared in *Erythea* (**3**: 123. 1895). It contains critical remarks upon numerous species, and descriptions of one new species of Cereus and two of Mamillaria.— J. M. C.

NEWS.

PROFESSOR DR. H. AMBRONN has been called to the assistant professorship of botany in the University of Jena.

PROFESSOR J. W. TOUMEY, of the University of Arizona, has been appointed assistant professor of forestry in the new school of forestry at Yale University.

WITH THE BEGINNING of the present volume of the BOTANICAL GAZETTE, Dr. J. C. Arthur, on account of ill-health and pressure of work, retires from the position of an active and responsible editor. For eighteen years he has been identified with the journal, and has been a large factor in whatever success it has achieved. In 1882 he became an associate editor, and in 1886 he became an editor, sharing financial as well as editorial responsibilities. The GAZETTE will not lose his counsel and active cooperation, for his connection will be continued as an associate editor.

THE FOLLOWING FELLOWS in Botany have been appointed by the University of Chicago for 1900–1901: S. E. M. Coulter (Hanover College), B. E. Livingston (University of Michigan), and A. A. Lawson (University of California). A. C. Moore, a Fellow of last year, has been appointed Assistant. Mr. J. E. Webb, who received the Master's degree in June, takes charge of the work in botany at Morgan Park Academy, a preparatory school of the University. Mr. F. L. Stevens, who received the Doctor's degree in June, is to spend two years abroad in botanical work as an honorary fellow.

WE LEARN from *Science* (June 15) that the appropriations for the Department of Agriculture for the fiscal year ending June 30, 1901, amount to $4,023,500, being an increase of more than $280,000 over the appropriations for the preceding year. Of this amount $720,000 is for the experiment stations in the forty-eight states and territories, $12,000 for the stations in Alaska, $10,000 for a new station in Hawaii, and $5000 for an investigation and report to Congress on the agricultural resources and capabilities of Puerto Rico. The appropriations which directly concern the botanical establishments are as follows: Division of Botany, $43,080; Division of Forestry, $40,000; Division of Vegetable Physiology and Pathology, $34,500; Division of Agrostology, $25,100. The Biological Survey receives an appropriation of $30,300; while the appropriation for the Division of Seeds is increased from $130,000 to $170,000, an increase due in large measure to a petition of some 225 members of the House of Representatives.